ACTA RADIOLOGICA

EDITA IUSSU SOCIETATUM RADIOLOGICARUM
DANIAE, FENNIAE, NORVEGIAE ET SUECIAE

VOL. 46 JULY—AUGUST 1956 FASC. 1—2

SEPTEMBER 13—17, 1955

President's Speech at Opening Ceremony

First of all, Professor LINDGREN, thank you very much for the great honour you have done me in investing me with this chain of Office. During the week that I have the privilege of wearing it I assure you all that I will attempt to uphold the high traditions this Symposium has developed.

Next, on behalf of all of us, may I thank you and the Committee of the Third Symposium for this beautiful Gavel that you have just presented to us. Examining it, I see that it bears the usual qualities one associates with Swedish workmanship — beauty, strength and practical value.

Now, Ladies and Gentlemen, I would like to welcome you all to this Fourth Symposium Neuroradiologicum. Many of you have travelled a long way to join us at considerable trouble and expense. For some of you it is your first Symposium, for others your second or third, and for a few, a very few, your fourth. To all we extend a very hearty welcome.

The history of this Symposium was admirably described by Professor LINDGREN in his Presidential Address in 1952. I would invite those of you who did not hear it to read it in 'Acta Radiologica'. May I remind you, as he did, that this is a Symposium, not a Congress. Its purpose has always been a free exchange of ideas and discussion on as informal a basis as possible. We intend to maintain and foster this spirit. On this occasion more of us are meeting together than ever before. Some of you may think there are too many and that we have too many papers. We have indeed stretched the meeting over another day, partly because we discovered about a year ago, months after we had begun planning this Symposium, that the Second International Congress of Neuropathology was meeting in this same city in the same week. The opportunity of arranging a half day scientific session with them seemed much too good to miss, and as you know this joint session is arranged for tomorrow afternoon. I feel confident that it will be a great success.

I think you will agree that these circumstances have enhanced the interest of others, working in the field of neurology, in both meetings, and we welcome neurologists and neurosurgeons as joint scientific members of both our bodies. The interest in and the influence of neuroradiology is extending, and it is perhaps inevitable that more members should be enrolling and that more papers should be submitted. Although we have more papers we have still tried to leave adequate time for discussion.

Knowing Professor LINDGREN as I do, I feel he must have anticipated the fullness of our programme on this occasion and the important practical use that our Chairmen might have to make of this Gavel. I can only say that I hope it will not have to be put to too much use.

As you will have gathered from your programmes, our scientific and technical committees have staged exhibitions at the other end of this building in the Institute of Education. I hope you will all visit them during the course of the week as I am sure you will find both interesting.

I would like to welcome our Lady Associate Members, for whom our Ladies' Committee has prepared a programme.

And now I have much pleasure in declaring this Fourth Symposium Neuroradiologicum open.

James Bull

The following papers were delivered at the Symposium and are published in this issue of Acta Radiologica unless otherwise stated. They appear in the same sequence as read during the Symposium but with the titles, the wording of which in some instances has been slightly altered, in the language of the respective texts.

SPINE

McRae, D., Montreal	Asymptomatic intervertebral disc protrusions.
Jacobsen, H., Copenhagen	Suboccipital gas myelography in the diagnosis of herniated disc in the cervical segment.
Cramer, F. and Hudson, F., New York	Myelographically demonstrated lesions of the cervical intervertebral discs co-existing with tumors and other causes of myelopathy.
Walk, L., Eskilstuna	Clinical significance of discography.
Cowie, T., Glasgow	Congenital spinal deformities of surgical importance.
Lefèbvre, J., Klein, M., Lepintre, (Mme) J. et Fauré, C., Paris	Étude radiologique des tumeurs médullaires chez l'enfant.
Jirout, J., Prague	Studies in the dynamics of the spine.

PNEUMOGRAPHY

Liliequist, B., Stockholm	The anatomy of the subarachnoid cisterns.
Bull, J. W. D., London	The normal variations in the position of the optic recess of the third ventricle.
Jirout, J., Prague	Changes in the size of the subarachnoid spaces after the insufflation of air.
Lenzi, M. und Canossi, G., Modena	Zwei Jahre Erfahrungen unserer cisternoencephalographischen Technik.
Lenzi, M., Canossi, G., Reggiani, R. und Bergonzini, R., Modena	Das Problem der subduralen Luft bei der Cisterno-Encephalographie.
Ruggiero, G., Paris	Diagnostic value of encephalographic examination of the subarachnoid space.

DISCUSSION OF ENCEPHALOGRAPHY

DAVID, M., Paris

RADIOGRAPHIC EXAMINATION OF THE SKULL

DU BOULAY, G., London	The significance of digital impressions in children's skulls.
SCHIFFER, K., Mainz	Zur Ableitung von Entwicklungsvorgängen aus dem Röntgenbild des Schädels.
FISCHGOLD, H., METZGER, J. and JUSTER, M., Paris	Radiographie segmentaire du conduit auditif interne dans les neurinomes de la 8ème paire.
GORDON, D., London	The use of ultrasonic rays in diagnostic neuroradiology. (Not received.)

TUMOUR DIAGNOSIS

SJÖGREN, S., Stockholm	The anterior choroidal artery.
WICKBOM, I., Gothenburg	Angiography and pneumography in the diagnosis of slightly space-occupying supratentorial tumours.
FALK, B., Stockholm	Radiologic diagnosis of intraventricular meningeomas.
LIMA, A., Lisbon	Errors and their causes in the interpretation of cerebral angiograms. (Not received.)
COLUMELLA, F. and PAPO, I., Milan	Vertebral angiography in supratentorial expansive processes.
LÖFGREN, F. O., Lund	Vertebral angiography in the diagnosis of hydrocephalus and differentiation between stenosis of the aqueduct and cerebellar tumour.
GVOZDANOVIĆ, V., Zagreb	Changes in the superficial veins in cases of intracranial expanding processes.
LAINE, E., DELANDTSCHEER, J. M., GALIBERT, P. and DELANDTSCHEER-ARNOTT, (Mme) G., Lille	Phlebography in tumours of the hemispheres and central grey matter.
HOFFMAN, G., FRANÇOIS, J., CHABÉAU, P., LEMAHIEU, F., Ghent	Angiography in sellar, parasellar and suprasellar tumours. (Not received.)

TENTORIAL HERNIATION

Joint session with 2nd International Congress of Neuropathology

AZAMBUJA, N., LINDGREN, E. and SJÖGREN, E., Stockholm	Tentorial herniations. I. Anatomy. II. Pneumography. III. Angiography.
FOLEY, J. M., Boston	Cerebral infarction as a cause of herniation of the temporal lobe. (Not received.)
PIA, H. W., Giessen	The pathogenesis of the vascular lesions of the occipital lobes in raised cerebral pressure. (Not received.)
WOHLMAN, L., Sheffield	Pituitary necrosis in raised intracranial pressure. (Not received.)
JOHNSON, R. and YATES, P. O., Manchester	I. Clinico-pathological aspects of pressure changes at the tentorium. II. Brain stem haemorrhages in expanding supratentorial conditions.
LE BEAU, J. and GRUNER, J. E., Paris	Clinical diagnosis of temporal herniations and intrinsic lesions of the brain stem, based on an anatomical study of 50 cases. (Not received.)
POOL, J. L., New York	The neurosurgical treatment of herniation of the uncus in cases of brain tumour and pathological changes. (Not received.)

ANGIOGRAPHY—TECHNIQUES

LINDGREN, E., Stockholm	Another method of vertebral angiography.
STAUFFER, H. M., MURTAGH, F., MOKROHISKY, J. F. and PAUL Jr., R. E., Philadelphia	Biplane stereoscopic cerebral angiography.
VIALLET, P., SENDRA, L., CHEVROT, L., COMBE, P., DESCUNS, P. and AUBRY, P., Algiers	Nouvelle méthode d'angiographie cérébrale simultanée totale par injection intraveineuse rapide.
PHELINE, CH., VIALLET, P., SENDRA, L., COMBE, P., CHEVROT, L. and AUBRY, P., Algiers	L'utilisation de l'angiographie cérébrale totale simultanée par voie intraveineuse chez l'enfant.

DISCUSSION OF ARTERIOGRAPHY

RUGGIERO, G., Paris

RAPID SERIAL ANGIOGRAPHY

GREITZ, T., Stockholm	Rapid serial angiography.
SCHIEFER, W., Cologne	Der diagnostische Wert einer funktionellen Serienangiographie bei intracraniellen Prozessen.
VERBIEST, H. and FEDDEMA, J., Utrecht	Cerebral cine-angiography with the image intensifier.
VIETEN, H., Delft	Cerebral serial angiography on 70 mm film size.

SUBARACHNOID HAEMORRHAGE

WALSH, L. S., London	Subarachnoid haemorrhage.
KRISTIANSEN, K., Oslo	A clinical and radiologic evaluation of spontaneous subarachnoid hemorrhage.
MOUNT, L. A. and TAVERAS, J. M., New York	Cerebral angiographic studies following surgical treatment of intracranial aneurysms. Angiographic evaluation of results.

Discussion:

HAUGE, T., Oslo	Atrophy within the brain stem area following injection of Thorotrast into the vertebral artery.

ANGIOGRAPHY—MISCELLANEOUS

BROMAN, T. and OLSSON, O., Lund	Experimental comparison of diodonum with sodium acetrizoate with reference to possible injurious effects on the blood-brain barrier.
DECKER, K., Munich	Der Spasmus der A. Carotis interna.
WORINGER, E., LANGS, A., BRAUN, J. et BAUMGARTNER, J., Colmar	Étude sério-angiographique de la dynamique circulatoire du cerveau.
KAPLAN, H., New York	Arteries of the brain. An anatomic study.
NORMAN, O., Lund	Angiographic differentiation between acute and chronic subdural and extradural haematomas.

VERJAAL, A., the Hague, in collaboration with NEYENS, N. J., Haarlem	Thrombosis of the middle cerebral artery.
FROWEIN, R., Frankfurt	Angiographische Befunde bei cerebralen Gefässerkrankungen und ihre Beziehungen zu den klinischen Syndromen.

STEREOTAXY

TALAIRACH, J., RUGGIERO, G. and DAVID, M., Paris	The roentgenologic contribution to stereotaxic investigations of the brain and its practical application in pathologic conditions.
LEKSELL, L., Lund	A stereotaxic technique for intracerebral surgery. (Not received.)
MURTAGH, F., WYCIS, H. T., ROBBINS, R., SPIEGEL-ADOLF, M. and SPIEGEL, E. A., Philadelphia	Visualization and treatment of cystic brain tumours by stereo-encephalotomy.
SCHALTENBRAND, Wurzburg	Development of stereotaxic technique in orthoradiography. (Not received.)

ISOTOPES IN NEURORADIOLOGIC DIAGNOSIS

KRAMER, S., BURTON, L. K. and TROTT, N. G., London	Radioactive isotopes in the localization of brain tumours.
BROWNELL, G. and SWEET, W., Boston	Scanning of positron-emitting isotopes in diagnosis of intracranial and other lesions.
SELVERSTONE, B., Boston	Diagnosis of supratentorial tumours by means of K^{42}. (Not received.)
JOHANSON, C., Stockholm	The accuracy of neuroradiology in the diagnosis of intracranial mass lesions. (Not received.)

MISCELLANEOUS PROFFERED PAPERS

LODGE, T., Sheffield	Bone, joint and soft tissue changes following paraplegia.
ARDRAN, G. and KEMP, F. H., Oxford	Radiologic investigation of pharyngeal and laryngeal palsy.
LEFÈBVRE, J., LEPINTRE, (Mme) J., FAURÉ, C. et PEREZ, J., Paris	Résultats de l'angiographie cérébrale au cours des hémiplégies cérébrales infantiles.

FASIANI, G., Milan	Cerebral angiography in acute brain injuries.
BREIT, A. und PEIFFER, J., Munich	Mehrfache Angiographien während der Röntgenbestrahlung von Hirngeschwülsten.

The following two papers are based on the authors' contributions to the scientific exhibition:

HANELIN, J. and BAKAY, L., Boston	Encephalography of sellar and parasellar tumors with particular reference to the antero-posterior projection and olfactory sulci.
JEFFERSON, A. and SHELDON, P. W. E., Oxford	Transtentorial herniation of the brain as revealed by the displacement of arteries.

FROM MONTREAL NEUROLOGICAL INSTITUTE, MONTREAL, CANADA

ASYMPTOMATIC INTERVERTEBRAL DISC PROTRUSIONS

by

Donald L. McRae

There are many ways of classifying intervertebral disc protrusions. In this paper they will be discussed under the following three classifications and I intend to show that disc protrusions are common but that they seldom produce symptoms.

1) Directional: upward or downward; anterior or lateral; posterior.

2) Pathological: bulging of annulus fibrosus; herniation of nucleus pulposus; rupture of annulus fibrosus; combinations of these.

3) Clinical: symptomless and symptom-producing.

The words 'intervertebral disc protrusion' will be used to mean that some part of the disc is outside of the normal boundaries as described in anatomical textbooks. I will consider the disc to be composed of two parts, the annulus fibrosus and the nucleus pulposus. The cartilage plate, which some authors describe as part of the disc, I consider to be the articular cartilage of the vertebral body and not part of the disc.

Bulging of the annulus fibrosus. PÜSCHEL in 1930 described progressive diminution in water content of the nucleus pulposus with advancing age. This is chemical evidence of degeneration and it can be correlated with histologic evidence of degeneration. Desiccation reduces the turgor of the nucleus pulposus, consequently the adjacent vertebral bodies come together, and the annulus fibrosus may bulge outwards (Fig. 1). The amount of bulging depends partly on the degree of desiccation of the nucleus, partly on the rate at which it occurs, and partly on the amount of vertical movement of the articulating facets that is possible. Bulging tends to be greater where the edges of adjacent vertebrae are closest, such as along the concave side of a scoliotic curve (Fig. 2), anteriorly in the thoracic region, and posteriorly in the cervical and lumbar regions.

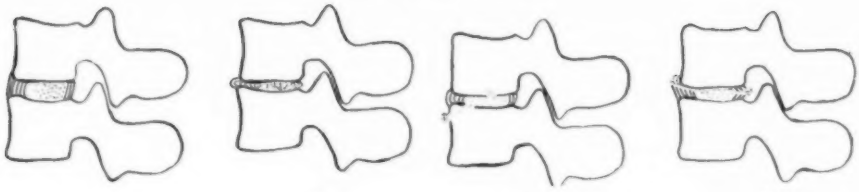


Fig. 1. Diagram of various types of disc protrusion. a) Normal. b) Desiccated nucleus. c) Nuclear herniations. d) Ruptures of annulus.

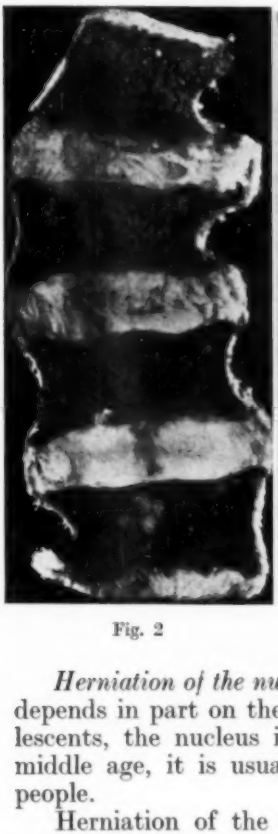


Fig. 2

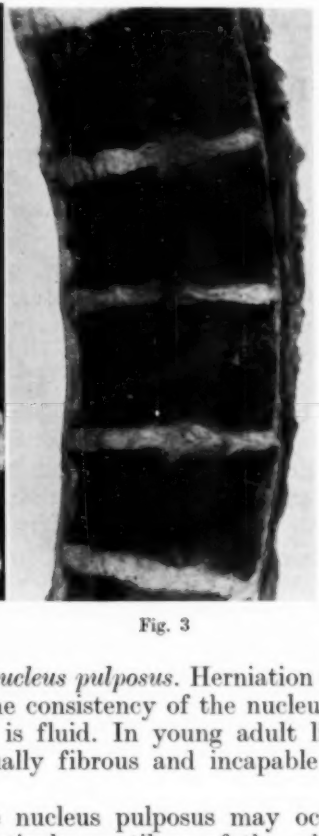


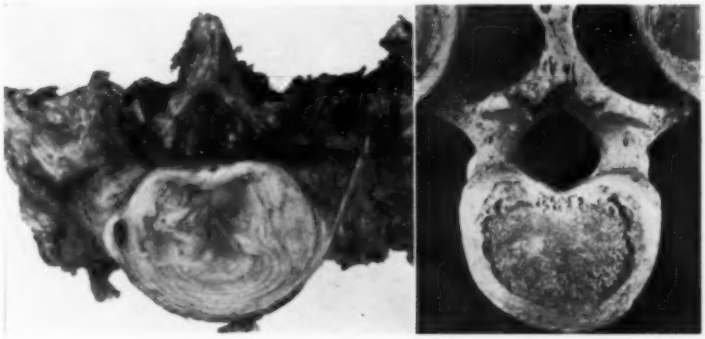
Fig. 3

Fig. 2. (From COLLINS: *Pathology of Arthritic and Spinal Diseases.*) Coronal section of a spine in a scoliotic patient. On the concave side of the curve the annulus fibrosus bulges, and bony fringes are seen on the edges of the vertebral bodies.

Fig. 3. Sagittal section through the 7th to 10th thoracic vertebrae, showing Schmorl's nodes, and also anterior bulging of the intervening discs.

Herniation of the nucleus pulposus. Herniation of the nucleus pulposus depends in part on the consistency of the nucleus. In children and adolescents, the nucleus is fluid. In young adult life, it is semi-fluid. In middle age, it is usually fibrous and incapable of herniation in most people.

Herniation of the nucleus pulposus may occur upwards or downwards through the articular cartilage of the adjacent vertebral bodies (Fig. 1). This type of herniation usually occurs without rupture of the annulus fibrosus. If much nuclear material escapes into or through



a b

Fig. 4. (From BEADLE.) a) Lumbosacral disc viewed from above. b) First lumbar vertebra viewed from above.

the vertebral body, and if the articulating facets lie in a vertical plane, then the vertebral bodies will come together and the annulus fibrosus will bulge (Fig. 3). Herniation of the nucleus pulposus forwards, backwards, or laterally can occur only if the annulus fibrosus is ruptured.

Rupture of the annulus fibrosus. Rupture of the posterior part of the annulus fibrosus occurs somewhat more often than rupture of the anterior or lateral parts. This is probably because the annulus fibrosus is narrowest posteriorly (Fig. 4a) and because the compact bony rim on the articular surface is least developed posteriorly (Fig. 4b). The fibers of the annulus fibrosus may rupture without pulling away from their bony attachments or they may rupture at their attachment to the vertebra above, or the vertebra below (Fig. 1). If the annulus ruptures at both points of attachment, an isolated piece of annulus will be produced, the so-called sequestrated disc.

If the nucleus pulposus is fluid or semi-fluid, it will usually herniate when the annulus ruptures. If it is fibrous and solid, or if the nucleus has already escaped into the vertebral body to form a Schmorl's node, it will not be able to herniate.

Combinations of the preceding disc lesions. All who have dissected many adult spines know that combinations of bulging, herniation and rupture are the rule, not the exception. In most middle-aged and elderly people, there are herniations of the nucleus pulposus into the bodies of many of the vertebrae, bulging of the annulus fibrosus at many levels, and rupture of the annulus at several levels. Anterior, posterior and lateral herniations of the nucleus pulposus are difficult to detect in these people, since the nucleus is often fibrous and hard to differentiate from the annulus.

Results of dissection of the spine. Disc protrusions can be seen directly. Running the finger up the anterior, lateral or posterior aspect of the vertebral bodies in the spine of a middle-aged or elderly person feels like running the finger up a washboard. When the hard lumps that are felt are sectioned, it is found that they are usually made up of both disc and bone. Sometimes, they are mostly bone with very little disc, and such are most often found at the lateral edges and postero-lateral corners of the cervical bodies. Sometimes, they are mostly disc with very little bone, and such are most often found in the lumbar region.

It is likely that many of the bony fringes on the edges of the vertebral bodies are the result of stripping of periosteum due to disc protrusion. Lateral bony fringes are largest and most common on the concave side of a scoliotic curve where there is maximum bulging of the annulus fibrosus (Fig. 2). Anterior fringes are commonest on the anterior concavity of the thoracic spine. However, posterior fringes are uncommon along the posterior concavity in the cervical and lumbar regions. The explanation of this discrepancy is not yet available. It may be that the periosteum on the posterior aspect of the vertebral bodies is stripped less often than it is on the anterior or lateral aspects. The bony fringes on the edges of the vertebral bodies in Marie-Strümpell arthritis are not caused by disc protrusion. However, if a patient with Marie-Strümpell arthritis has a protruded disc at one level, the bony fringes at that level will curve around the protruded disc.

COVENTRY, GHORMLEY and KERNOHAN sectioned the lumbosacral disc in eighty-eight consecutive patients at autopsy, ranging in age from one to seventy-nine years, and found posterior ruptures of the annulus fibrosus in 8 %. They suggested that since they did only mid-sagittal sections, they missed many ruptures and that the true frequency of posterior ruptures must be greater than 8 %. They found anterior bulging of this disc (L5—S1) many times but only one true anterior rupture of the annulus fibrosus.

BEADLE stated that extrusions of the nucleus pulposus were often seen on or near the posterior aspects of the intervertebral discs. They were most frequent in the lower dorsal and upper lumbar regions but rare in the cervical region. They were present in 56 of 368 spines (15.2 %) and were frequently multiple, one case having seven of them. They were never seen under thirty years of age and most cases were over fifty. He also noted that once or twice small bony fringes were found on the posterior edges of the vertebral bodies and suggested that they were evidence of old posterior extrusions. He believed that traumatic extrusions of the discs into the spinal canal occurred and considered them to be prolapses of the whole disc. He found them most often in

the lumbar region, especially at the fourth and fifth discs. He also stated that upward or downward prolapse of the nucleus pulposus was found in 38 % of 3,000 spines at autopsy.

I have had the opportunity of inspecting or dissecting 33 complete spines. In 12 of the 18 spines that were from patients over thirty years of age, there were disc protrusions. Multiple upward and/or downward protrusions of the nucleus pulposus were present in all twelve (66 %). Eleven of the eighteen (61 %), had anterior and/or lateral disc protrusions, and more than one disc was involved in each case. Seven of the eighteen (39 %), had posterior protrusions. Of these, one had a single posterior protrusion at the C3—C4 level, but the other six had multiple posterior protrusions. The reason why our cases show higher percentages of disc protrusions than most series reported is that we did not section the spine in only one plane. We sectioned each disc along the plane of any palpable disc and/or bony protrusion (Fig. 5).

Fig. 5. Lower thoracic spine viewed from in front showing spurs at two levels slightly lateral to the mid-sagittal plane and a fringe at the intervening level. Mid-sagittal section showed anterior bony fringes and anterior disc protrusion at only one level. Para-sagittal sections showed anterior bony spurs and anterior disc protrusions at three levels.

Radiologic investigation of the spine

Radiologic evidence of disc protrusion may be of several types. The small round or square defect in the upper or lower part of a vertebral body outlined by compact bone on the roentgenogram is accepted by all of us as a Schmorl's node, an old upward or downward protrusion of nucleus pulposus.

The bony fringe projecting from the edge of a vertebral body allows one to deduce the position of the underlying intervertebral disc. If the fringe projects at an angle to the normal annulus fibrosus, there is invariably a protrusion of disc tissue in the corresponding direction (Fig. 6). This sign of disc protrusion must be emphasized. In the 33 spines that we have radiographed and sectioned, the direction of the bony fringe always showed the position of the underlying disc. Posterior fringes are particularly important to recognize, and we believe that

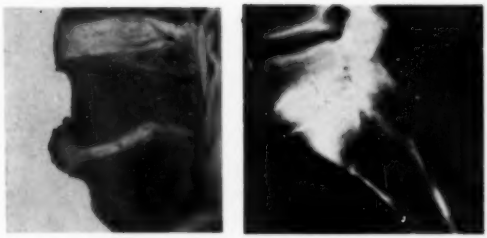


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Fig. 6. a) Sagittal section of L5 and S 1. Anterior protrusion of lumbosacral disc and anterior bony fringes partly outlining it. b) Lateral roentgenogram of specimen before it was cut.

Fig. 7

Fig. 7. Lateral roentgenogram. Bony fringe on postero-inferior edge of body of L3. Stereoscopically it was seen to lie to the right of the midline. Right-sided postero-lateral disc protrusion at L3—L4 level at operation.

with stereoscopic lateral films we can often tell if a posterior fringe on a lumbar body is in the midline, or to the right, or to the left (Fig. 7).

It is difficult to decide if a posterior bony fringe on a cervical body is midline. Oblique or stereoscopic lateral films will show if a posterior cervical fringe is laterally situated close to the intervertebral foramen. If the oblique or stereoscopic lateral films do not show the fringe to be close to the intervertebral foramen, then one can deduce that it is in the midline. If the bony fringes on the edges of the vertebral bodies are parallel to the fibres of the normal annulus fibrosus, they are not evidence of disc protrusion (Fig. 1). The bony fringes must project at an angle to the plane of the normal annulus, preferably almost at right angles, before one can say that they are evidence of disc protrusion (Fig. 8). Occasionally, an anterior protrusion of a lumbar disc is seen because it contrasts with the retro-peritoneal fat (Fig. 9).

Visualization of a calcified nucleus pulposus in an abnormal position between the adjacent vertebral bodies is suggestive of protrusion of that disc in the direction of the abnormal position. However, calcification may appear eccentrically in the nucleus so the above-mentioned sign is not absolute. If the calcified nucleus pulposus is no longer between the vertebral bodies, then the diagnosis of intervertebral disc protrusion can be definitely made (Fig. 10).

Posterior disc protrusions may be demonstrated by myelography but not all defects in the myelogram are disc protrusions. When a column of oil moves, it may separate, and at the point where the separation

Fig. 8

Fig. 9

Fig. 8. Photograph (*left*) and roentgenogram (*right*) of a thin mid-sagittal slice of cervical spine showing posterior bony fringes at right angles to the normal direction of the fibres of the annulus fibrosus. They outline posterior disc protrusions.

Fig. 9. Anterior protrusion of the L2—L3 disc shown by contrast with the retro-peritoneal fat.

is going to occur the column first becomes narrow. The oil column separates opposite the discs, due to the slight posterior prominence of normal discs and of the adjacent edges of the vertebral bodies. Since the oil column usually separates when it is moving, separation is most often seen in the lower thoracic region as the oil passes upwards and in the upper thoracic region as the oil passes downwards. Separation may occur with a stationary column of oil, if only a thin layer of oil is present. We always use 10 or 15 cc of oil (Ethiodan) to ensure good filling of the spinal subarachnoid space and therefore are seldom troubled by separation of the stationary oil column. I have investigated this point by running small and large quantities of oil under direct vision up and

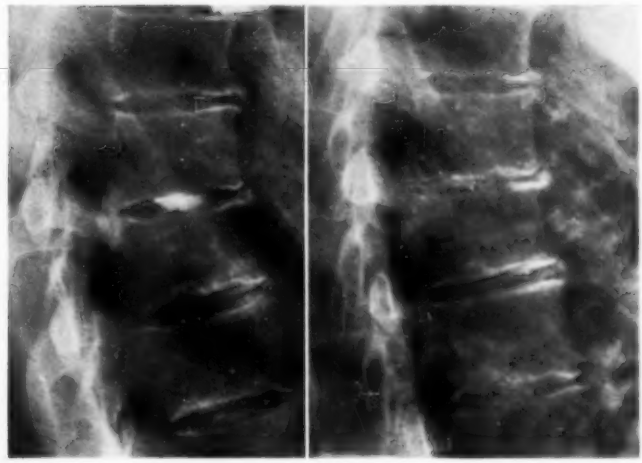

Fig. 10. Lateral chest films of 1949 (*left*) and 1951 (*right*) showing progressive backward and downward displacement of calcified nucleus pulposus. The patient has never had back pain or neurologic signs.

down the spinal canal of three spines from which the vertebral arches and spinal cord had been removed. The specimen consisted of the vertebral bodies, pedicles and the trough of dura in which the spinal cord had lain (Fig. 11). Satisfactory photographs could not be made because the oil was transparent and because of the deep shadows on the anterior surface of the spinal canal, in such a specimen. The narrowing of the oil column, just before separation took place, always occurred at, or slightly upstream from the disc. A fisherman knows that water flowing over a log, or a low dam, tends to flow over the centre of the obstruction. Slight narrowing of the moving oil column at the level of each disc may be called the "dam" effect. We also know that a stream of water goes around a rock that rises above the water. The same stream rises up in a hump over a submerged rock and then falls away on the downstream side of it. Oil passing around or over disc protrusions does the same, and if one watches the head of the advancing oil column, one can diagnose the posterior disc protrusions in the lower thoracic and upper lumbar regions that BEADLE found so often.

When the above-mentioned fluoroscopic findings are present, or when a rather sharply angled indentation of the oil column is shown on two or more films, a diagnosis of posterior disc protrusion can be safely made in the upper lumbar or thoracic region. Post-mortem myelograms

Fig. 11. Photograph of a thoracic spine after removal of the laminae, the spinous processes, the posterior dura, and the spinal cord. The lumps of plasticene at each end keep the oil in the spinal canal.

Fig. 12. Lateral film of excised spine made in the erect position with 80 cc of lipiodol in the subarachnoid space. Multiple posterior disc protrusions in the lower thoracic and upper lumbar regions confirmed by subsequent dissection of the spine.

Fig. 11 Fig. 12

show posterior protrusions in the lower thoracic and upper lumbar regions surprisingly often (Fig. 12).

Special mention must be made of posterior cervical disc protrusions and their demonstration by myelography. The fourth cervical vertebra has this shape (Fig. 13) when viewed from above. The spinal canal is said to be triangular in cross-section, but this is only true at the point where the pedicles are attached to the vertebral body. Above and below this point, the vertebral body bulges backwards so that there are shallow gutters on each side. In these gutters lie the nerve roots in their dural and arachnoidal sleeves. In cervical oil myelograms (Fig. 14), deep collections of oil on each side of a central thin layer of oil are seen, partly because the spinal cord occupies the central part of the subarachnoid space, and partly because the oil collects in the sleeves and gutters lateral to the vertebral bodies and discs. In some people, these gutters are several millimeters deep and the oil in the sleeves and gutters produces the anterior edge of the shadow of the oil column in lateral myelo-

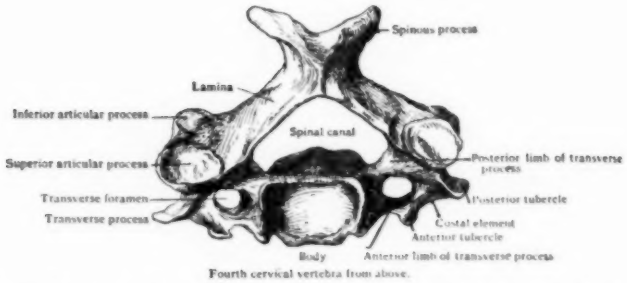

Fig. 13. (From PIERSOL: *Human Anatomy.*) The fourth cervical vertebra from above.

grams. In such cases, midline posterior protrusions of cervical discs may not be seen in the lateral myelogram.

In another type of patient with shallow gutters, the anterior surface of the oil column may show indentations just above the junction of the pedicles and bodies, and these may be incorrectly diagnosed as posterior cervical disc protrusions (Fig. 15). In patients with a cervical kyphosis, the kyphos will divide the oil column into two parts. The filling defect is due to the bone but may be mis-diagnosed as tumour, or midline cervical disc protrusion (Fig. 16). One must remember that the lower cervical cord fits in its tube of dura rather tightly and that the dural tube is very close to the vertebral bodies and discs in front. The layer of oil anterior to the cervical cord is thin, and even low posterior protrusions of disc and/or bone will rise above the central shallow layer of oil and produce striking defects in the myelogram. It is necessary to show a constant central filling defect on two or three films, each made with different degrees of flexion and extension of the neck, before definite myelographic diagnosis of midline posterior cervical disc protrusion is made.

Osteoarthritis of the joints between the cervical facets is accompanied by proliferation of bone on the edges of the facets and by hypertrophy of the articular capsules. Such abnormal joints press on the lateral and posterior edges of the cervical subarachnoid space and should not be mis-diagnosed as disc protrusions on the myelogram. Slightly oblique films will show these defects to be postero-lateral and allow one to differentiate them from disc protrusions. The laminae and the ligaments between them indent the cervical subarachnoid space when the head is extended, therefore myelogram films should be made with the neck in neutral position, or with the neck slightly flexed to prevent defects due to the relaxed ligamenta flava appearing on the films.

One must be canny in the interpretation of cervical myelograms.

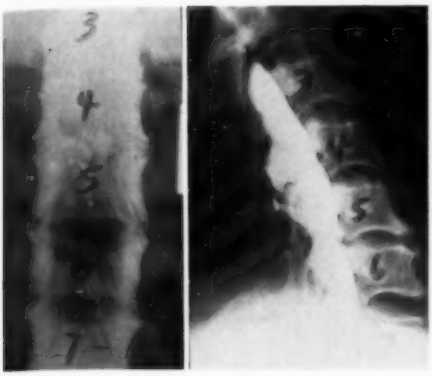

Fig. 14. Myelogram films in a patient with deep gutters on each side of spinal cord. Anterior surface of oil column is anterior to posterior surface of bodies of fourth and fifth cervical vertebrae at some points.

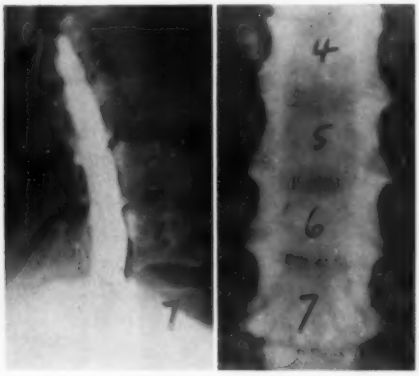

Fig. 15. Apparent small indentations in the anterior part of the oil column at the level of the C4—C5 and C5—C6 discs.

Good conventional films must be available to allow one to estimate the effect of osteophytes on the posterior edges of the cervical bodies, the effect of a cervical kyphosis, or of arthritis of the joints between the facets. Then one must judge from the myelogram whether the patient has deep or shallow gutters and whether the cervical cord fits tightly or loosely into its tube of dura. Only after these factors are considered, can one accurately interpret the cervical myelogram.

Frequency and significance of cervical disc protrusions

Upward and downward protrusions of cervical discs can only be diagnosed with surety by sectioning the spine. They are said to be rare. Nearly all authors consider them to be of no clinical significance.

Anterior cervical disc protrusions were present in 39 % of our eighteen spines from patients 30 years of age and over. Anterior osteophytes accompanied each of these anterior disc protrusions. Lateral cervical disc protrusions were present in 28 % of the same group and lateral osteophytes were present in 34 %. Posterior cervical disc protrusions were present in 34 % and posterior osteophytes were found in 34 %. Some of these specimens had disc protrusions at more than one level, and some had protrusion of one disc in more than one direction.

Two hundred and forty consecutive radiographic examinations of the cervical spine in patients, age 30 years and over, were divided into three groups as follows. The first group consisted of patients with

a

b

Fig. 16. a) Lateral cervical spine film made with the neck extended showing an irreducible mid-cervical kyphosis. b) Myelogram films of same patient showing the bone rising like an island above the oil. It is impossible to diagnose or to exclude midline posterior protrusion of discs at this level.

neck-shoulder-arm syndrome thought to be due to postero-lateral cervical disc protrusion. The second group was made up of patients with disease of the cervical spinal cord in whom cervical spondylosis or midline posterior cervical disc protrusion was thought to be the probable cause. The third group consisted of patients without signs or symptoms of cervical spondylosis or cervical disc disease. Many of these were patients with sciatica who were to have lumbar myelograms. Others were patients with head injury but no neck complaints, patients with spinal cord tumours, with myelitis, or, occasionally, patients with multiple sclerosis. The number of thin discs and the number of bony fringes projecting backwards from the posterior edges of the vertebral bodies were compared in the three groups at each cervical level. Approximately equal numbers of normal-appearing cervical roentgenograms occurred in the asymptomatic and symptomatic groups of the same age.

For example, in the age group 50 to 59 years, there were 20 patients with neck-shoulder-arm syndrome. Only one of these had normal cervical roentgenograms. Nine had one or more cervical discs that were thin, and were associated with bony fringes projecting backwards from the vertebral body at the same level and 10 had one or more thin cervical discs without an associated posterior bony fringe. In the 20 cervical spines, there was a total of 39 thin discs and 19 posterior bony fringes. In the same age group, there were 8 patients with cervical spinal cord disease,

probably due to spondylosis or midline posterior disc protrusion. None had normal cervical roentgenograms. Six had one or more thin discs with backward projecting bony fringes from the vertebral bodies at the same level. One had a thin disc without associated bony fringing, and one had posterior bony fringes without thinning of the discs. In the 8, there were a total of 15 thin discs and 15 posterior bony fringes. There were 22 patients of the same age (50 to 59 years) without cervical symptoms or signs, and of these only 3 had normal cervical roentgenograms. Seven had thin discs with associated bony fringes projecting posteriorly. Three had thin discs without associated posterior bony fringes, and 4 had posterior bony fringes without disc thinning. This group showed a total of 28 thin discs and 30 posterior bony fringes. As described above, the thin discs were considered to be degenerated and/or protruded discs. The bony fringes projecting backwards from the edges of the cervical bodies were considered to outline posterior cervical disc protrusions. The small differences in the numbers of degenerated and posteriorly protruding discs in the three groups in this decade are of no statistical significance.

In the age group 60 years and over, and in the group 30 to 39 years of age, there was no significant difference in the radiographic findings between the asymptomatic and the symptomatic groups. In the age group 40 to 49, there was possibly a significant difference. In this decade, there were 29 patients with neck-shoulder-arm syndrome. Eight had normal cervical roentgenograms. Eleven had one or more thin discs, with associated posterior bony fringes, and 3 had thin discs without associated posterior bony fringes. There were 8 patients with cervical cord disease, none of whom had normal cervical films. Six of the 8 had thin discs with posterior bony fringes, projecting from the bodies of the vertebrae at the same level. One had a thin disc with no associated bony fringes and one had posterior bony fringes without disc thinning. There were 54 asymptomatic patients, 15 of whom had normal roentgenograms and 17 of whom had one or more thin discs with associated posterior bony fringes. Four had thin discs with no associated bony fringe, and 14 had posterior bony fringes but no thin discs. These figures show little difference. However, there were 38 thin discs in the 29 patients with neck-shoulder-arm syndrome, 13 thin discs in the 8 patients with cervical cord disease and only 37 thin discs in the 54 patients without symptoms. This large difference unfortunately is of no practical value since it is a difference of degree rather than a difference of kind. There was no significant difference in the degree of disc thinning, or in the size of the posterior bony fringes, between the symptomatic and asymptomatic groups. Whether or not there were symptoms referable to the neck, bony fringes were seen projecting at an angle to the direction of the annulus fibrosus

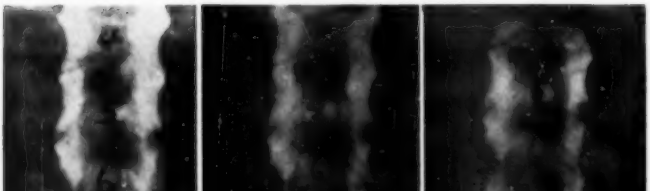

Fig. 17. Cervical myelogram films with neck in different degrees of flexion and extension in a man, age 54, with low-back pain and sciatica but without symptoms in the neck, shoulders, arms or hands. Medium-sized midline posterior protrusions of the C4—C5 and C5—C6 discs; medium-sized left postero-lateral protrusion of the C6—C7 disc.

at approximately two disc levels in each cervical spine, most often at the C5—C6 and the C6—C7 levels. This suggests that there were at least two cervical disc protrusions per patient, whether he had symptoms or not.

One hundred and fifty-nine consecutive recent cervical myelograms in patients, age 30 and over, were analysed after dividing them into symptomatic and asymptomatic groups. The patients in whom there were no symptoms of cervical disc protrusion were mainly patients who had low back pain and/or sciatica, and in whom a cervical myelogram was carried out at the same sitting as the lumbar myelogram. Either 10 or 15 cc of oil were injected for each myelogram, and a 180-degree tilting fluoroscopic table was used to ensure good filling of the cervical subarachnoid space. Defects in the cervical oil column that were debatable, or that were shown on only one film, were scored as questionable. If the defect completely, or almost completely obstructed the cervical subarachnoid space, the lesion was called large. If the defect was over 5 mm in diameter, it was called medium in size. If the subarachnoid space at a certain disc level filled with oil on any one film it was scored as normal, even though other films suggested disc protrusion at that level. There was no significant difference in the number of abnormal myelograms in the symptomatic and asymptomatic groups. There were 40 patients with symptoms of midline, posterior, or postero-lateral cervical disc protrusions, and they had 54 medium or large posterior protrusions, while the 119 patients, who had had no cervical symptoms or

signs, showed 127 medium, or large, posterior protrusions, practically the same percentage. For example, in the age group 50 to 59 years, the 12 patients with symptoms of cervical disc protrusions had 8 grossly abnormal myelograms, showing a total of 24 medium-sized disc protrusions and one very large disc protrusion. Only one of these patients had a completely normal myelogram. The 29 asymptomatic patients in the same age group had 15 grossly abnormal myelograms, showing 31 medium-sized disc protrusions and one large disc protrusion. Six of the 29 showed entirely normal cervical myelograms. The analysis suggests that any patient over 30 years of age, no matter what symptoms or signs he presents, is apt to have a posterior cervical disc protrusion demonstrated, if he happens to have a myelogram (Fig. 17). The side to which a posterior cervical disc protrusion projected correlated very well with the side to which the symptoms were referred. In patients with right as well as left sided postero-lateral protrusions of one cervical disc, the largest protrusion was always on the side of the symptoms.

Frequency and significance of lumbar disc protrusions

One hundred and sixty-one consecutive recent lumbosacral roentgenograms of patients, age 30 and over, were examined after being divided into asymptomatic and symptomatic groups. We scored only 7 of the 161 roentgenograms as entirely normal. Some of the patients showed minor abnormalities, such as Schmorl's nodes at 1 or 2 levels, forcing us to put them in the abnormal group. We recorded congenital abnormalities and found more 6th lumbar vertebrae than sacralized 5th lumbar vertebrae. We always radiographed the thoracic spine, and often radiographed the entire spine when the lumbar spine was examined during the time this study was being carried out, so that we could accurately number the vertebrae.

Posterior bony fringes signifying posterior disc protrusions at the last two disc levels (so-called sciatic hooks) were significantly more common in patients with low back and/or root pain than in asymptomatic patients. Thin discs were also significantly more common in patients with low back and/or root pain. For example, in the age group 50 to 59 years, there were 37 patients with low back pain and/or sciatica. None had normal lumbar roentgenograms. Eighteen had one or more thin discs with bony fringes projecting backwards from the vertebral body at the same level. Seventeen had thin discs without associated bony fringes. In the same age group, there were 25 patients without low back pain or sciatica. Two had normal lumbar roentgenograms. Only 3 had thin discs with associated posterior bony fringes, and only 5 had thin discs without posterior bony fringes. Nuclear expansions producing deep

concavities on the articular surfaces of L4, L5 and S1 were definitely more common in the symptomatic group. Anterior and lateral bony fringes, signifying anterior and lateral disc protrusions, were only slightly more common in the symptomatic than in the asymptomatic patients. However, it must be emphasized that exactly the same radiological changes may be seen in two patients at the same age, one with no present or past history of low back pain or sciatica, and the other with a history of recurring lumbago and sciatica. For example, in the age group 40 to 49 years, there were 32 patients with low back pain and/or sciatica. None had completely normal lumbar roentgenograms. Five had one or more thin discs with associated bony fringes projecting backwards from the vertebral bodies. Thirteen had one or more thin discs with no bony fringes, and 2 had posterior bony fringes without disc thinning. In the 32 patients, there were a total of 26 thin discs and 15 posterior bony fringes. In the same age group, there were 15 patients without back pain or sciatica and again none had completely normal lumbar roentgenograms. Six had thin discs with associated posterior bony fringes coming from the adjacent vertebral body. Two had posterior bony fringes without disc thinning and 5 had thin discs without associated bony fringing. The fifteen had a total of 21 thin discs and 10 posterior fringes.

One hundred and sixty-nine consecutive recent lumbar myelograms on symptomatic and asymptomatic patients, age 30 and over, were analysed. The asymptomatic patients were patients who were having myelograms for spinal cord disease, or for cervical disc disease, and who denied having had lumbago and/or sciatica. We had only 46 asymptomatic patients for control purposes. A significantly greater number of abnormal lumbar myelograms (93 in all) was found in the 109 symptomatic patients, 30 to 59 years of age, than in the asymptomatic group. The latter group showed only 23 abnormal myelograms in the 40 examinations. In this age group, there was a significantly greater total number of posterior and postero-lateral lumbar disc protrusions in the symptomatic than in the asymptomatic group. There was an average of two posterior or postero-lateral disc protrusions per myelogram in the symptomatic group, and an average of only one posterior or postero-lateral disc protrusion in the asymptomatic group. The large posterior lumbar disc protrusions were much more common in the symptomatic than in the asymptomatic group. In the 14 symptomatic and 6 asymptomatic patients, age 60 and over, all of the myelograms were considered to show medium-sized, or large posterior or postero-lateral disc protrusion. The total number was two and a half times as great in the symptomatic as in the asymptomatic group, however. The significance of minor deformities in the lumbar myelogram has been demonstrated by CHILDE.

These minor deformities were hard to define and analyse on a rigid statistical basis. Therefore we only scored myelographic deformities that were medium-sized or large. Again, I must emphasize that exactly the same picture may be found in the asymptomatic patient as in the one with symptoms (Fig. 18). It is interesting that there was an average of two posterior lumbar disc protrusions per myelogram in the patients with symptoms. If the T10—T11 and the T11—T12 levels were included, there was an average of 3 posterior disc protrusions per myelogram in the group with low back pain and/or sciatica. Usually, but not always, in the patients with lumbar nerve root symptoms who had multiple posterior disc protrusions, the largest myelographic defect was on the side of the symptoms. There was also fairly good correlation between the side to which nerve root symptoms were referred and the side on which a single postero-lateral disc protrusion was shown.

Fig. 18. Myelogram of a woman, age 60, with progressive spinal cord disease who denied ever having had low back pain and/or sciatica. Medium-sized right and left postero-lateral protrusions at the L4—L5 level.

We did not have enough patients with thoracic disc protrusions to analyse. BEADLE's report, and the results of our post-mortem work, agree that upward and downward thoracic disc protrusions are very common. It is believed that they rarely cause symptoms. Anterior, posterior, and lateral thoracic protrusions are also fairly common, yet they seldom produce symptoms.

Conclusions

It is important when we speak of an intervertebral disc protrusion that we specify asymptomatic or symptom-producing disc protrusion and we specify the direction in which it protrudes.

Disc protrusions can be shown at post-mortem, on conventional roentgenograms, and by myelography in the three areas of the spine of almost all patients over forty years of age.

Posterior disc protrusions, single or multiple, small or large, may be present without the patient complaining of symptoms at the present time or in the past. Since it is unusual to find patients who never have had neck or low back pain, or nerve root symptoms, the number of asymptomatic posterior disc protrusions is not accurately known. The

results of this investigation of a small number of patients suggests that nearly everybody, forty years of age or older, has at least one posterior cervical and one posterior lumbar disc protrusion.

It is felt that the reports of pre-employment spine roentgenograms are unreliable, since any person applying for a job is apt to deny having had back pain and/or sciatica. The tendency to reject workers who have congenital spinal abnormalities, spinal "arthritis", postural defects and so on, is deplored. It will lead to the rejection of many men over forty on account of anatomical changes that in many cases are of no significance and which in other cases are of only secondary importance. Pre-employment spine roentgenograms for purposes of future comparison seem advisable in heavy industry, however.

It is felt that the significance of posterior protrusions of cervical discs in patients with disease of the cervical spinal cord is not yet clear. Over-emphasis on the importance of cervical disc protrusions has led to cervical operations in patients with minor abnormalities in the cervical myelogram. Some patients with the syndrome of degenerative disease of the cervical spinal cord and marked myelographic abnormality have improved without operation (COSGROVE). Further work is necessary to assess the significance of the ligamentum flavum, of arthritis of the apophyseal joints, of tight dentate ligaments and of the anterior spinal artery as well as of the disc protrusions themselves.

SUMMARY

Intervertebral disc protrusions disclosed by dissection as well as by post-mortem radiography and myelography are described. In 60 % of patients over the age of 30 years, multiple anterior and lateral disc protrusions were found, and in 40 % of these there were also posterior disc protrusions, usually multiple. Comparing roentgenograms and myelograms of asymptomatic patients with those of patients having symptoms and signs referable to back or neck, the same percentage of disc protrusions as in the post-mortem material was found.

ZUSAMMENFASSUNG

Zwischenwirbelscheibenprotrusionen, welche man sowohl bei der Sektion als auch bei an Leichen ausgeführten Röntgenuntersuchungen und Myelographien vorfand, werden beschrieben. Bei 60 % der mehr als 30 Jahre alten Patienten fand man multiple vordere und seitliche Wirbelscheibenprotrusionen und bei 40 % dieser Patienten lagen auch hintere Wirbelscheibenprotrusionen vor, auch diese gewöhnlich multipel. Beim Vergleich der Röntgenbilder und Myelogramme von symptomenfreien Patienten mit denjenigen von Patienten mit Beschwerden und Symptomen, die auf den Rücken oder den Hals zurückzuführen sind, fand man prozentuell die gleiche Anzahl von Wirbelscheibenprotrusionen wie im Sektionsmaterial.

RÉSUMÉ

L'auteur décrit les protrusions du disque intervertébral découvertes par dissection et par radiographie et myélographie post-mortem. Chez 60 % des sujets âgés de plus de 30 ans il a trouvé de multiples protrusions discales antérieures et latérales, et chez 40 % d'entre eux il y avait aussi des protrusions discales postérieures, habituellement multiples. La comparaison de radiographies et de myélographies de sujets asymptomatiques avec celles de sujets présentant des signes fonctionnels et physiques imputables au rachis dorsal et cervical a donné le même pourcentage de protrusions discales que sur le matériel post-mortem.

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FROM THE DEPARTMENT OF RADIOLOGY, BISPEBJERG HOSPITAL (DIRECTOR: KJELD ANDERSEN), COPENHAGEN, DENMARK

SUBOCCIPITAL GAS MYELOGRAPHY IN THE DIAGNOSIS OF HERNIATED DISC IN THE CERVICAL SEGMENT

by

H. H. Jacobsen

Suboccipital gas myelography combined with tomography visualizes the spinal subarachnoid space from the occipital foramen to the terminal cistern. Gas is less irritating than positive opaque media of the Abrodil (Skiodan) type which are, moreover, only applicable in the lumbar region. Gas also has the advantage of being completely absorbed, unlike iodized oils. Pantopaque, for instance, has been seen in the spine several years after myelography. Despite all efforts, its complete aspiration after the examination seems to be impossible.

On the other hand, gas does not, like the positive media, permit a study of the root sheaths of the spinal nerves; furthermore, tomography — which is indispensable for a definite evaluation — is difficult or quite impracticable in the presence of scoliosis. The procedure also requires a tomograph with a couch that can be tilted head down. In addition, old persons and cardiac patients cannot tolerate the prolonged, uncomfortable head-down position.

Summing up, it may be said that the lumbar subarachnoid space is examined with opaque media of the Abrodil type, the lower thoracic segment and the lumbar space with high lumbar gas myelography combined with tomography, and lastly the cervical space and the upper thoracic segment with suboccipital gas myelography. Pantopaque should only be used for old persons and cardiac patients, or where abnormal curvatures of the spine prevent tomography.

The technique has been described by LINDGREN (1939). The application of this procedure for diagnosing spinal tumours was discussed in detail by ODÉN at the Third Symposium Neuroradiologicum in Stockholm 1952, and some case reports were submitted in the Danish Radiological Association in 1954 (JACOBSEN). The procedure is also applicable for diagnosing herniated discs in the cervical segment.

By suboccipital gas myelography herniated discs in the cervical segment have been diagnosed in 35 cases. In 13 of these, the diagnosis was confirmed by operation, in one non-operated case by pantopaque myelo-

graphy, while for various reasons 19 patients have not had surgery. In two instances the operations failed to reveal any herniation. One of these patients had been examined at a time while the author's routine in reading these films was still insufficient. Reviewing these films, I can now find only an insignificant protrusion which does not reduce the lumen of the spinal canal or touch the cord. In the other case, I cannot find any definite explanation of the incongruence between the roentgen and operative findings. The clinical findings were suggestive of fibrosis of the root sheaths and the operative record does not give the impression that exploration was made with a particular view to herniation of an intervertebral disc. Moreover, it must be borne in mind that a soft herniation may disappear when the head is bent forward and re-appear when the neck is extended (BANG, 1955).

In the following, the roentgen and operative findings in 4 cases will be discussed and illustrated by one typical myelogram.

Case 1. 56-year-old male. Suboccipital gas myelography in 1954 (1282/54) showed moderate protrusion of disc between 5th and 6th cervical vertebrae. On a level with the disc between the 6th and 7th there was a larger prominence of soft tissues into the gas opacity, very probably representing a herniation. *Operation:* Slight protrusion of disc between 5th and 6th without compression of the root. The disc between 6th and 7th was hard and more prominent, and there was pronounced constriction of the root sheath of the 7th cervical root.

Case 2. 33-year-old male. Suboccipital gas myelography in 1954 (G 434/54) showed marked herniation of the thin disc between 4th and 5th cervical vertebrae (Fig. 1). It seemed to be pressing upon the cord. *Operation:* Left hemilaminectomy on the 4th cervical vertebra and the upper part of the 5th. The 5th cervical root showed some posterior prominence, and with a dissector a protrusion was felt. It appeared, however, to be considerably larger on the right side. Then, complete laminectomy was performed on the 4th and 5th cervical vertebrae. As expected, the protrusion was considerably larger on the right. The dura was opened in the midline. The cord proved to be displaced far backward by the protrusion.

Case 3. 59-year-old male. Suboccipital gas myelography in 1954 (G 1391/54) showed flat protrusion of the disc between the 2nd and 3rd cervical vertebrae and a more typical herniation between the 3rd and 4th. There seemed to be a herniation also between the 4th and 5th cervical vertebrae, but at this site the appearances were more doubtful. *Operation:* Extradural examination revealed a firm protrusion on a level with the disc between the 3rd and 4th cervical vertebrae. The dura was divided in the midline. At the site of the protrusion the cord looked somewhat thin and atrophic. After cutting the attachment of the ligamentum denticulatum it was possible to mobilize the dura to the extent of revealing a mass, the size of half the kernel of a hazel nut, bulging through the anterior aspect of the dura, approximately in the midline. An incision was made into the dura anteriorly and into the prominence which, as expected, proved to be an old herniation of the intervertebral disc.

Case 4 had a peculiar history: It was a woman aged 61. For the past few years she had been suffering from slowly progressing spastic paresis of the left leg. In the right leg she had a slight sensation of unrest, and in the left arm periodically moderate weakness. The objective signs were mild, diffuse paresis of the left leg with slight spasticity and hyperreflexia, left-sided ankle clonus, and left-sided Babinski. Lumbar puncture showed

Fig. 1. Case 2. Herniation between the 4th and 5th cervical vertebrae pressing upon the cord.

normal pressure, Queckenstedt's test was normal, and the spinal fluid showed normal protein and cell contents. A complete blood study revealed no abnormality. *Encephalography* was normal apart from slight central atrophy. *Myelography* in 1955 (G 484/55) showed distinct, round protrusions of soft tissues into the anterior gas opacity behind the thin discs between the 4th and 5th, as well as between the 5th and 6th cervical vertebrae. *Operation:* The roots were free on both sides, but in the midline the protrusions were encountered. The left half of the cord had to be practically pushed backward over the prominence between the 5th and 6th. As the herniations proved hard as bone, only decompression was performed.

Three months after the operation, the progression of the symptoms had been arrested, and the condition was, if anything, better than before the operation.

The reason why I particularly want to emphasize this last patient is that unlike all the others she had no root symptoms, only showing signs of pyramidal tract lesion which was with great likelihood caused by the cervical herniations.

SUMMARY

Reporting four case histories, the author discusses the use of suboccipital gas myelography in the diagnosis of herniated cervical intervertebral disc.

ZUSAMMENFASSUNG

Der Verfasser berichtet vier Krankengeschichten und diskutiert den Wert der subokzipitalen Gasmyelographie für die Diagnostik der zervikalen Diskushernien.

RÉSUMÉ

L'auteur présente quatre observations et discute l'emploi de la myélographie gazeuse sous-occipitale dans le diagnostic des hernies discales cervicales.

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FROM THE NEUROLOGICAL INSTITUTE, NEW YORK, U. S. A.

MYELOGRAPHICALLY DEMONSTRATED LESIONS OF THE CERVICAL INTERVERTEBRAL DISCS, CO-EXISTING WITH TUMORS AND OTHER CAUSES OF MYELOPATHY

by

Fritz Cramer and *Frank Hudson*

In recent years the importance of ruptures and degenerative-proliferative disorders of the intervertebral discs, in the genesis of painful and paralytic affections of the nerve roots and spinal cord, has become increasingly clear. The increasing use of myelography as a diagnostic tool, and its correct use, has permitted the exact localization and the earlier diagnosis and removal of spinal cord tumors. It has also shed light on some hitherto obscure conditions by establishment of their discogenetic etiology. In some areas it has come to supplant much of the highly detailed clinical examinations and rationale which occupied the neurologist or neurosurgeon. As a consequence the greater burden of responsibility has fallen upon the roentgenologic member of the diagnostic team.

Because of this newer emphasis upon myelography, the needs for flawless technique and for exact interpretations are correspondingly increased. It seems inevitable that the prevalence of disorders of the intervertebral discs, and of their neurologic manifestations, has tended to overshadow the spinal cord tumor, which formerly took diagnostic precedence. In some of the cases to be presented here, this preoccupation with the discogenetic lesions led to failure to recognize the presence of the spinal cord tumors which were responsible for the neurologic manifestations, and led to either needless or wrongly directed surgery. In this discussion the findings are correlated from the view of the neurosurgeon, rather than the roentgenologist; by review of the findings it is hoped that impetus may be given toward more accurate pre-operative diagnoses.

Four cases of spinal cord tumor will be discussed: 3 intramedullary,

1 extramedullary, co-existent with disc disease. Of these, the latter is still living. Autopsies were obtained on the other three.

Case 1. 49-year-old male. Clinical history began 3½ years before admission. Neurologic examination on admission showed right hemiparesis with spastic wide-based gait; poor equilibration and spontaneous clonus of the right leg; paresis of the XI and XII cranial nerves; diminished vibratory perception in right leg, hypalgesia over right face and 2—8 cervical dermatomic segments, right hyperreflexia, absent abdominal reflexes, and a right Babinski sign. Complete manometric block was demonstrated with a spinal fluid protein of 172 mg %. *Myelogram:* Almost complete block at the C5-6 level with large ventral ridges demonstrated at the C4-5 and C5-6 levels with evidence of cord compression. However, enough of the contrast medium passed into the high cervical region; abrupt widening of cord at C3-4 level was noted, which extended up to the foramen magnum. *Operation:* Ventral ridges were confirmed; a large solid intramedullary tumor was found to occupy the right half of the cervical cord between C1 and C4, which displaced the posterior columns to the left. Patient developed gradual respiratory and cardiac failure and expired two hours post-operatively. *Autopsy:* Astrocytoma of the cervical spinal cord C1 to C5, with extension into the caudal medulla.

Case 2. 42-year-old male, with a history of 4½ months' duration. Neurologic examination on admission: Spastic paraparetic gait, worse on left, weak intrinsic muscles of both hands, worse on left, poorly delineated hyperalgesia over right 5th finger and left 3rd, 4th and 5th fingers; patellar and Achilles tendon reflexes were slightly increased bilaterally, right abdominal reflex was absent; bilateral Babinski. On lumbar puncture normal dynamics were demonstrated; spinal fluid protein level was 120 mg %. *Myelography* was believed to reveal herniated nucleus pulposi at C4-5 and C5-6 levels, with possibility of another at the C3-4 segment. The amyotrophic lateral sclerosis syndrome was considered secondary to the cervical disc disease, and the patient was discharged to be followed on conservative therapy but was re-admitted a few months later for cervical laminectomy and exploration. Then, no herniation of the intervertebral discs was found but indication of some angulation of the cord at 5th and 6th cervical segments by ventral osteoarthritic ridges. Nine months after onset of illness, patient was readmitted because of complaint of difficulty in swallowing, with changes in voice. Brain stem involvement was found with compromise of lower cranial nerves. Spinal fluid protein was increased to 184 mg %, with normal pressure and cell content. The patient received a series of roentgen treatments but deteriorated steadily and died some thirteen months after onset. *Autopsy:* Very extensive neoplasm in brain and upper cord; it showed evidence of having begun as an astrocytoma and then to have taken on the features of a glioblastoma. It was particularly prominent in the cervical cord at 5th and 6th segments. In addition, protrusions of discs at 5th, 6th and 7th cervical levels were described for a measurement of 1—2 mm.

Case 3. 63-year-old male with a history beginning 2 years before admission. Examination showed paresis of upper extremity much greater on the right, spastic paresis of right lower extremity with spasticity of both legs; adiadokokinesia bilaterally, greater on the right, with stereoanesthesia of hands bilaterally, greater on the left; absent vibration perception in forearms and hands, with decreased positional sense in fingers bilaterally, hypalgesia over right neck and shoulder; hyperreflexia was seen in both lower extremities and in right upper extremity, with right Hoffmann and Babinski signs. Complete manometric block on lumbar puncture, confirmed by *myelography;* spinal fluid protein level was 65 mg %. *Surgery:* Bony ridges at the levels of the interspaces at C3-4, C5-6 and C6-7 with, what appeared to be, an intraspinal cystic collection of fluid at the C3 level. Four dentate ligaments were sectioned bilaterally, to provide decompression of the cord, and the patient did well for two days, but at that time became

quite suddenly quadriplegic. It was feared that a localized blood clot might be present. The wound was reexplored for such a possibility but none was found; the patient developed respiratory difficulties and expired. *Autopsy:* Ependymoma of spinal cord at the 4th cervical segment extending up into the medulla with a syrinx at either end of the tumor.

Case 4. Male with 9 years progressive disability. Neurologic examination: Trunkal ataxia, mildly spastic gait, positive Romberg, drift of left extremities, impaired rapid alternating movements in all extremities, clumsiness of non-equilibratory coordination; markedly impaired position and vibration perception in both upper and lower extremities with stereoanesthesia of hands; hypalgesia bilaterally, worse on the right and sparing the face; generalized hyperreflexia, worse on the left; bilateral Babinski sign. Lumbar puncture disclosed a partial manometric block; spinal fluid protein level was 93 mg %. *Myelography* performed elsewhere was thought to give evidence of a herniated nucleus pulposus at the C6-7 interspace, but operation did not reveal this. *Myelography* performed at this institute showed an extramedullary spinal cord tumor at the C1-2 level on the left, with additional evidence of a herniated nucleus pulposus at the C3-4 level on left, and of the herniated disc at C3-4 on the right; both lesions were removed.

The spinal cord. In the non-tumor cases, the spinal cord is, despite compression, contained within normal maximal limits. In cases with intramedullary cord tumor, the cord is at some point in excess of the widest measurement given for the normal. In the block due to adhesions of the arachnoid, the cord fails to be visualized, not at the level of the interspace as with a disc or protruding central ridge, but at the level of the adhesions, which may occur at any point.

The proximal radicular nerve roots. In the appearance of that portion of the nerve root which is most proximal to its insertion into the ventral lateral sulcus, the nerve root can usually be followed to this insertion. However, this pattern is disturbed in the cases under discussion, in a manner characteristic for the abnormality. The proximal radicular patterns in extramedullary cord tumor, if visible at all, will follow the line of displacement of the spinal cord itself. The patterns in the case of the herniated disc and the central hypertrophic osteoarthritic spurs can be followed virtually to their normal line of insertion into the cord, except in cases of total block in the subarachnoid space where, of course, they may be traced to the line of block. The block itself corresponds with the intervertebral disc and the nerve root sheath which can usually not be seen. Individual distorsion of the root may be found, usually on one side, as it traverses an extruded portion of disc or protruding spur. However, it is extremely important to note that because herniated nuclei are frequently multiple, an error in localization is frequently made with two adjacent lesions, where the more caudally placed disc shows a block apparently, but the higher interspace is the site of the compression.

Thus, there is distinction to be made between the design made by the proximal nerve roots in solid intramedullary tumors and cystic tumors of the spinal cord. A solid tumor, such as an astrocytoma, invades and distorts the spinal cord in an irregular fashion and may elect either one

side or the other, in either the dorsal or ventral portion of the cord. In surgical explorations the (dorsal) nerve roots are seen to conform to the pattern of distortion of the spinal cord, and the line of dorsal nerve roots will de displaced to the degree that the posterior portion of the cord is invaded and distorted by the tumor; usually the displacement occurs laterally. However, in the myelogram it is usually only the ventral nerve roots that are seen, and in the presence of tumors that are solid the nerve root patterns will, for the most part, be eliminated, in strong contrast to the normal appearance; those that can be distinguished will be seen to be asymmetric. Cystic spinal cord tumors, *e. g.*, the ependymoma and/or the syrinx, show another characteristic nerve root pattern consistent with the pathology of the tumor which, being a central lesion, enlarges the cord in a fairly symmetric, fusiform pattern. At surgical explorations the dorsal nerve roots follow this pathology and will be displaced in a regular, divergent curve away from the midline, and far lateral to the normal curve of the dorso-lateral sulcus. Myelographic study will show the ventral nerve roots to follow the normal curve to the tumor level, where immediately the radicles will diverge from their normal insertion; they are usually not visible in the vicinity of the cord. Those lateral portions of the nerve roots, on the other hand, that can be seen, will be distorted and asymmetric.

Finally, in the case of (myelographic) subarachnoid block due to adhesions, the block will not correspond so exactly with the interspace as in the ruptured disc, but will vary with the degree of adhesion; moreover, their disappearance on the myelogram usually does not correspond to the nerve root but to the arachnoidal adhesion, which may or, as is more often the case, may not be adjacent to the nerve root.

The spinal fluid proteins in these 4 cases contrast with 4 others, with blocks, but no tumors. For spinal cord tumors they varied between 184 mg % to 65 mg %, for herniated nucleus pulposi and/or central hypertrophic osteoarthritic projections between 49 mg % to 36 mg %, and for disc disease with atrophic myelopathy and arachnoidal block due to adhesions between 132 mg % to 63 mg %.

That there is a definite trend toward an increase in the spinal fluid protein level in the cases with spinal cord tumor is evident. It has been consistent enough to warrant serious attention. It seems probable that in the one case with atrophic myelopathy, and arachnoidal adhesions that were severe, the increase in protein level may be accounted for on the basis of chronicity of the disease process (history began 10 years prior to admission). In any event, it may be concluded that a high cerebrospinal fluid protein level should warrant serious consideration of a spinal cord tumor, unless the clinical evidence, or the myelogram definitely excludes this possibility.

SUMMARY

On the basis of a study material of spinal cord tumors and disc herniations in the cervical region, the authors emphasize that in cases with intramedullary tumors the spinal cord always exceeds the width of the maximal normal measurement, while in ventral compression by disc herniation it is always within the normal maximal limit. In cases with disc lesion and extramedullary tumor, the proximal nerve roots can be followed to their normal insertion in the lateral sulci, with local deformities caused by herniation or tumor, while in cases with intramedullary tumor they tend to be obliterated in the tumor region.

ZUSAMMENFASSUNG

Auf Grund eines Materials von Rückenmarktumoren und Zwischenwirbelscheibenbrüchen in der Zervikalgegend betonen die Verfasser, dass in Fällen mit intramedullären Tumoren das Rückenmark immer die Breite des maximalen Normalwertes übersteigt, während die Breite bei der ventralen Kompression durch einen Zwischenwirbelscheibenbruch immer innerhalb der normalen Höchstwerte liegt. In Fällen mit Zwischenwirbelscheibenbruch und extramedullärem Tumor können die proximalen Nervenwurzeln bis zu ihrem normalen Eintritt in die lateralen Sulci gefolgt werden, mit lokalen Deformierungen durch die Hernie oder den Tumor. In Fällen mit intramedullärem Tumor neigen sie zur Obliteration in der Tumorgegend.

RÉSUMÉ

Se basant sur l'étude de cas de tumeurs de la moelle et de hernies discales de la région cervicale, les auteurs soulignent que dans les cas de tumeur intramédullaire le diamètre de la moelle est toujours supérieur au maximum normal, alors que dans la compression ventrale par hernie discale il est toujours inférieur à la limite supérieure normale. Dans les cas de lésion discale et de tumeur extramédullaire, il est possible de suivre la partie proximale des racines nerveuses jusqu'à leur insertion normale dans les sillons collatéraux, avec les déformations locales causées par la hernie ou la tumeur, alors que dans les cas de tumeur intramédullaire leur image tend à disparaître dans la région de la tumeur.

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CLINICAL SIGNIFICANCE OF DISCOGRAPHY

by

L. Walk

Although the technique and the roentgen findings in discography have been reported in the literature, the clinical significance of the method has not been analysed in detail.

Our material comprises 200 cases, with 310 discs examined, and is divided into 4 groups: A) normal, B) disc rupture with only slight deformity of the nucleus pulposus, C) degenerated disc, and D) degenerated disc with rupture.

A detailed analysis of the clinical findings revealed that these groups are associated with relevant neurologic symptoms and signs, and that there are two neurologic syndromes caused by the lumbar intervertebral disc: 1) compression of the nerve by the disc, and 2) irritation of the nerve by perineural spread of the contents of the nucleus pulposus, occurring through a disc rupture. Compression is characterized by numbness, but pain on coughing is absent; a strongly positive Lasègue sign may be found in cases of various duration up to some years, and changes in reflex, sensibility, and extensor paresis are frequent. Irritation is characterized by pain on coughing as an important symptom, but numbness is found only exceptionally; a strongly positive Lasègue is frequent in acute cases, but rapidly diminishes, and after 3 to 4 months is found only exceptionally; reflex, sensibility, and extensor changes are less frequent than in compression. A detailed analysis of the neurologic findings presented by the lumbar intervertebral disc will be published later. It may appear curious to analyse neurologic symptoms and signs generally considered a part of elementary medical education, but discography has rendered it possible to investigate the relation of neurologic findings to intervertebral disc changes more in detail than has been reported in the literature to date.

How does the surgeon evaluate discographic findings? Disc prolapses are found in Groups B and D if there is detachment of cartilage or there are bulging edges to the rupture. If these are absent, negative surgical findings are to be expected. The soft contents of the nucleus pulposus are apparently not palpated by the surgeon. Pathologists record all disc ruptures with spread of the nucleus as prolapses; theoretically, this is correct, but it is not adequate for clinical purpose. Where there is only a rupture but no cartilage detachment, treatment should be conservative. Incision only, for decompression, is of doubtful value, as the escaping nuclear contents have a tendency to spontaneous spread. Prolapses are even found in Group C (degenerated disc with local posterior bulging). Radiating pain on discography is not a reliable indicator.

SUMMARY

The clinical significance of discography has been analysed in a material of 200 cases. The neurologic syndromes and surgical aspect of the intervertebral lumbar disc are discussed.

ZUSAMMENFASSUNG

Die klinische Bedeutung der Discographie ist in einem Material von 200 Fällen analysiert worden. Die neurologischen Syndrome und die chirurgischen Aspekte der Zwischenwirbelscheiben des Lendenrückens werden diskutiert.

RÉSUMÉ

Sur un matériel de 200 cas l'auteur a examiné l'intérêt clinique de la discographie. Il étudie les syndromes neurologiques et la chirurgie du disque intervertébral.

REFERENCE

WALK, L.: Diagnostic lumbar disk puncture. Clinical review and analysis of sixty-seven cases. Arch. Surg. 66 (1953), 232.

FROM THE RADIODIAGNOSTIC DEPARTMENT, WESTERN INFIRMARY, GLASGOW, SCOTLAND

CONGENITAL SPINAL DEFORMITIES OF SURGICAL IMPORTANCE

by

Thomas N. Cowie

Until comparatively recently, relatively little attention was paid to congenital malformations of the spine by the radiologist who encountered them in his routine work, and little attempt was made to analyse the deformities with any degree of accuracy. Unfortunately, the tendency to regard congenital malformations of the spine as largely of academic interest is still too prevalent, and it is not yet sufficiently widely recognised that each case of congenital spinal deformity, particularly in a child, adolescent, or young adult, represents a practical radiological problem.

In assessing the problem, three important questions must be answered:

1) Is the deformity of the vertebral column, by itself, likely to cause severe disability to the patient?

2) Is it associated with any malformation or lesion of the spinal cord or nerve roots?

3) Are either the bony or nervous lesions amenable to surgical treatment?

To answer these questions, accurate and detailed radiological analysis is essential, and this may necessitate serial examinations over a lengthy period, in most cases tomography, and in many cases myelography.

The first stage in radiological assessment of a congenital spinal deformity is analysis of its component parts. The help given by tomography in this analysis cannot be overstressed. Almost all writers on spinal deformities are agreed that the details of a deformity are rendered much more distinct by tomographs, and that these may reveal additional deformities not shown on the plain roentgenograms. The component parts of the deformity are essentially manifestations of three primary faults:

(1) vertebral fusion, (2) rachischisis (congenital fissure of the vertebral column), and (3) arrested or delayed development. The radiological features of these faults appear in the following table:

Table

Fusion	vertebral bodies
	laminae
	processes
Rachischisis	sagittal cleft vertebra
	spina bifida
	wide spinal canal
	mid-line spurs in spinal canal
Arrested development	hemivertebra
	coronal cleft vertebra

To complete this list, we must add deformity of pedicles.

The extent and combination of these individual features often enable the radiologist to decide or, at least, strongly suspect that there is an associated malformation of the spinal cord, meninges, or nerve roots. In some cases, a confident diagnosis of such malformation may be possible.

The radiologist should be on guard if he finds:

1) fusion involving more than two vertebrae, and especially if the laminae are involved in the fusion;

2) two or more sagittal cleft vertebrae;

3) widening of the spinal canal and, in particular, fusiform widening of a part of the spinal canal;

4) localised spina bifida combined with any of the foregoing faults;

5) extensive spina bifida.

The following faults are much less likely to be significant:

fusion of only two adjacent vertebrae;
single sagittal cleft vertebra;
localised spina bifida, unaccompanied by other defects;
hemivertebrae;
coronal cleft vertebrae (which are included in this list for the sake of completeness, but are unlikely to be encountered in practice, since, as ROWLEY has pointed out, they usually consolidate in the first few months of life).

The clinical picture must, of course, always influence judgment, and, in the latter group, symptoms or signs referable to the level of the deformity would be an indication to proceed with myelography. With no abnormal clinical findings in this latter group, however, it is probable

that there is no involvement of nervous tissue, and myelography is unjustified. When symptoms do occur in this group, they will most probably be due to direct pressure of bone on the nerve roots at the level of the deformity.

When the radiologic analysis suggests that the malformations are confined to the vertebral column, the problem becomes largely an orthopaedic one. In practice, this is almost exclusively the assessment of congenital scoliosis, a common lesion, but quite often not a serious one, since, as JAMES emphasizes, the multiple vertebral defects may cancel one another out, and the spine remain essentially straight. The curves may, however, progress, and become very serious and, for this reason, a radiographic check at, say, six-monthly intervals should be carried out. As an alternative to conservative treatment, the operations of spinal fusion and resection or enucleation of one or more hemivertebrae, as practised by WILES, are available. We may also hope for development of a method of controlling growth on one side of the spine by stapling, as NACHLAS and BORDEN have done experimentally in animals.

Returning to the features suggesting involvement of the spinal nervous system, the question of widening of the spinal canal deserves some amplification and, with it, that of deformity of the pedicles. Widening of the spinal canal I consider a most important sign, and especially the manner in which it is widened. The more marked degrees of widening can be identified without resorting to measurement (as in Fig. 1), but, in most instances, assessment of widening necessitates measurement of the interpedicular distances and comparison with tabulated figures (see Fig. 2). The now classical measurements made by ELSBERG and DYKE in 1934 are extremely useful, particularly if the graphic curves resulting from these measurements are consulted. FRANCIOSI found, in a very large series of normal subjects between the ages of 10 and 60, that age did not affect these so-called rachimetric curves. From personal experience, it is suggested that the pattern of these curves holds good in quite young children, which impression has been confirmed by LANDMESSER and HEUBLEIN in a series of 200 normal children between the ages of 1 and 15 years. In other words, although ELSBERG and DYKE's absolute measurements of interpedicular distance are not applicable in childhood, the comparative distances at chosen levels should maintain very similar ratios to those obtaining at the same levels in the normal adult. When an increased interpedicular distance in a single vertebra is encountered in association with a congenital deformity, it is unlikely to be of special significance. An example appears in a case of sagittal cleft vertebra described by SAMUEL. His illustration shows the vertebra in question to have a disproportionately large interpedicular measurement, but there was no real indication of cauda equina involvement. Likewise, occasion-

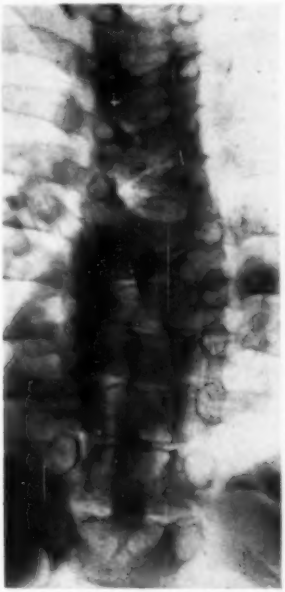

Fig. 1

Fig. 2

Fig. 1. Case of diastematomyelia. Marked widening of spinal canal. The pedicles, though widely separated, are not deformed or eroded.

Fig. 2. Widening of spinal canal requiring measurement for confirmation.

ally cases occur in which the whole of the spinal canal is wide but the normal pattern of the rachimetric curve is maintained, and there are no clinical signs of spinal cord involvement. These cases may almost certainly be assumed to be anomalies of only anatomical interest; their myelographic picture is of a uniformly wide but quite regular opaque column. In congenital deformities, it is widening of the spinal canal of a fusiform type which most commonly denotes an associated abnormality of the spinal nervous system, and this is a sure indication for myelography. Together with this type of widening, one should consider the shape of the pedicles. If they retain their normal shape, and show no evidence of pressure erosion, the lesion is very likely to be a diastematomyelia (Fig. 1). If the widening is associated with deformation of the medial aspect of some of the pedicles, it is probable that there is a mass within the spinal canal. HANNAN and GEIST point out very clearly, in this connection, how pedicle deformity is a function of the rate of growth of a tumour in the spinal canal. It may, but very rarely, be so slowly

growing that the canal shows only fusiform widening without pedicular deformity. More commonly, a slow-growing tumour produces decalcification or flattening of the inner aspect of the pedicles. Concavity or actual erosion denotes a more rapidly growing tumour. This is of practical value in differential diagnosis. The types of tumour occurring along with congenital spinal deformities are, in general, slow-growing. They may decalcify or flatten the pedicles; they infrequently erode them and very, very seldom erode the vertebral bodies.

Having dealt with the radiological features in general, we may now consider some of the surgically remediable conditions in which congenital vertebral deformities are associated with lesions of the spinal nervous system. These will be mentioned briefly, with a view to emphasising what the author considers to be the more helpful features in radiological differential diagnosis. The conditions are meningeal cysts, teratomatous tumours (particularly dermoids), and congenital fissures in the spinal cord (diastematomyelia).

In 1954, JACOBS et coll. reviewed 12 cases of *congenital, extradural meningeal cyst* from the literature and described a further personal case. In all but one of these cases, roentgenograms were available and, in every case, changes were present in the plain roentgenograms. Although the changes were mainly in the nature of true pedicle erosion, there also occurred widening of the spinal canal, kyphosis or scoliosis and, in one case, flattening of the vertebral bodies. It is difficult to conceive the latter feature as being of an acquired nature. JACOBS and his colleagues very reasonably state that the roentgen differential diagnosis is unsatisfactory. In myelograms, a fortunate chance may cause the cyst to be filled, enabling a positive diagnosis, but this will seldom occur. What JACOBS thought suggestive, however, was a combination of a partial block with an appearance resembling arachnoiditis. Unfortunately, this may occur in diastematomyelia and cannot, therefore, be regarded as an important differential point.

Teratomatous tumours, particularly dermoids, occur sufficiently frequently along with bony malformations of the spine to have attracted some notice in the literature. Typically, they cause widening of the spinal canal, very often of a fusiform type, but this is almost always combined with recognisable alteration in the appearance of the pedicles, varying from flattening or concavity of the medial aspects to actual erosion (Fig. 3). HANNAN and GEIST point out that destruction of the posterior aspects of the vertebral bodies can also occur, although this would, more often, suggest a diagnosis of extradural neurofibroma, the roentgen signs of which have been well described by BULL. With neurofibroma, however, there are not the concomitant vertebral anomalies which characterize the teratomatous tumours, and, as BULL indicates,

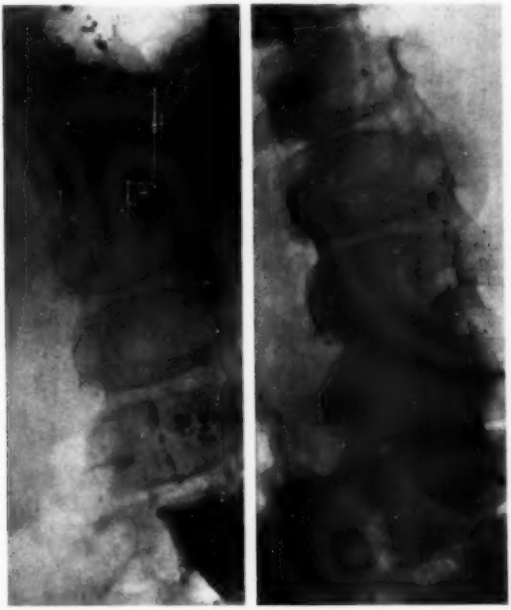

Fig. 3. Intraspinal dermoid tumour. Flattening of medial aspect of right pedicle of L 2 in particular.

if more than two adjacent vertebrae show radiological changes, the tumour is not likely to be a neurofibroma.

In the past five years, increasing recognition has been afforded to *diastematomyelia* by paediatric specialists and neurosurgeons. This interesting combination of congenital clefts in the spinal cord and vertebral anomalies, although rare, is more frequent than many conditions whose names are common knowledge. Unlike many of the latter, moreover, it is a condition which is amenable to treatment, and which may be diagnosed while symptoms are still minimal. I am impressed by the opening paragraph of CHAMBERS' report of a case in 1954. He says: "A mild impairment of function in one lower extremity noticed early in life, followed frequently by some incontinence, and usually associated with a slight to prominent abnormality of the back, consisting of a small dimple, a hairy patch, or an obvious bony deformity, may be a surgically remediable condition known as diastematomyelia." It is also worth noting that, according to SHOUL and RITVO, some cases of cervical spinal anomalies labelled as Klippel-Feil syndrome may be examples of this condition. The salient radiographic features of the condition are (Fig. 4) obvious

Fig. 4

Fig. 5

Fig. 6

Fig. 4. Case of diastematomyelia. Fusiform widening of spinal canal without deformity of pedicles; partial fusion of vertebral bodies; spina bifida, and prominent bony spur, just to the right of the midline.

Fig. 5. Midline lateral tomogram of same case as in Fig. 4. Fin of bone projecting posteriorly into the spinal canal from the posterior aspect of the mid-thoracic vertebral bodies.

Fig. 6. Case of diastematomyelia. Myelogram: Spur of bone in interval between opaque columns. At lower limit of picture: confusing pocketing of opaque medium.

fusiform enlargement of the spinal canal, usually with no deformity, or only minimal deformity, of pedicles, spina bifida, and multiple vertebral deformities including almost all of those listed earlier in this paper. The demonstration of a near midline bony spur or spicule in addition to some or all of the above is almost pathognomonic. Tomography may be of assistance in showing the latter jutting into the spinal canal (Fig. 5). The most conclusive evidence, however, is provided by myelography when, in a favourable case, it is possible to show the opaque column dividing round a translucent area, in the middle of which is the spur of bone. Unfortunately, it is not always possible to demonstrate this, and the myelographic picture is a disappointing one of pocket formation, odd filling defects, and streaks, a picture which, in fact, suggests adhesive spinal arachnoiditis (SEAMAN et coll.). It is not surprising that this oc-

curs. The irritation resulting from traction (intermittent or constant) on the transfixing bony and cartilaginous spur may be expected to produce meningeal changes of this kind. It certainly makes myelographic diagnosis more difficult (Fig. 6). It may, in such cases, be helpful to employ a larger quantity of opaque fluid than the average, but this is only a suggestion which the author has not meantime been able to test. Finally, I should like to draw attention to two further features of this condition which may cause diagnostic difficulty. The first is the occurrence of diastematomyelia along with an intraspinal dermoid tumour, as in a case which the author described in 1952. The second is that, inexplicably, the pedicles at the level of the fusiform widening of the spinal canal may show very marked flattening and deformity, truly suggesting an intraspinal dermoid. In the case illustrated by Fig. 7 (for which the author must thank Dr. STEVEN of the Glasgow and West of Scotland Neurosurgical Unit) the operation finding was simply a spike of bone at L 2—L 3, transfixing an abnormally low conus medullaris.

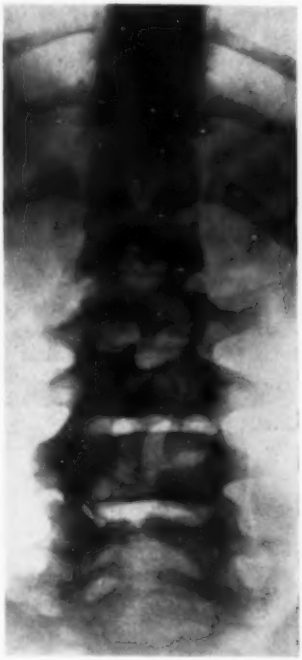

Fig. 7. Marked flattening of pedicles of L 2—L 3 suggesting an intraspinal dermoid tumour. Operation: no tumour but a spike of bone transfixing an abnormally low conus medullaris, *i. e.* an example of diastematomyelia.

In conclusion: Congenital spinal deformities should not be regarded as anatomical curiosities, but receive careful analysis along the lines suggested. If, as a result of this analysis, they merit inclusion in the group capable of producing disability, but amenable to some form of surgical treatment, this should be brought to the notice of the physician in charge of the case, even although there are no symptoms at the time. This is particularly true in the case of young children. If the child's doctor is forewarned, he is in a position to initiate surgical measures whenever symptoms declare themselves, or become sufficiently urgent.

SUMMARY

The details of congenital spinal deformities encountered in children, adolescents, or young adults should be analysed by careful radiography. This may allow the radiologist to decide whether the spinal nervous system is involved, and whether surgical

treatment is necessary or feasible. The principal neurosurgical conditions which may be disclosed are meningeal cysts, teratomatous tumours, and diastematomyelia. Differential diagnosis between these is difficult, but the more important radiographic features are stressed. One cannot place too great emphasis on the fact that such deformities are practical problems and not anatomical curiosities.

ZUSAMMENFASSUNG

Einzelheiten der kongenitalen Wirbeldeformitäten, die man bei Kindern, Jugendlichen und jüngeren Erwachsenen findet, sollten mit Hilfe sorgfältiger Röntgenuntersuchung analysiert werden. Diese kann dem Röntgenologen die Möglichkeit geben zu beurteilen, ob das spinale Nervensystem angegriffen ist und ob chirurgische Behandlung notwendig oder möglich ist. Die hauptsächlichen neurochirurgischen Zustände, welche nachgewiesen werden können, sind meningeale Zysten, teratomatöse Tumoren und Diastermatomyelie. Die Differentialdiagnose dieser Erkrankungen ist schwierig; die hierfür wichtigeren Röntgenbilder werden hervorgehoben. Man kann die Tatsache, dass derartige Deformitäten praktische Probleme und keine anatomischen Kuriositäten sind, nicht genug betonen.

RÉSUMÉ

Les détails des malformations rachidiennes congénitales rencontrées chez l'enfant, l'adolescent ou l'adulte jeune devraient être analysés grâce à un examen radiologique soigneux. Ceci pourrait permettre au radiologiste de décider si le système nerveux spinal est intéressé et si un traitement chirurgical est nécessaire ou possible. Les principales affections neurochirurgicales que l'on peut découvrir sont les kystes méningés, les tumeurs tératomateuses et la diastématomyélie. Le diagnostic différentiel entre elles est difficile, mais l'auteur souligne leurs caractères radiologiques les plus importants. On ne saurait trop insister sur le fait que ces malformations sont des problèmes pratiques et non des curiosités anatomiques.

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ETUDE RADIOLOGIQUE DES TUMEURS MEDULLAIRES CHEZ L'ENFANT

par

J. Lefèbvre, M. R. Klein, J. Lepintre et *C. Fauré*

Malgré la faible fréquence des tumeurs médullaires chez l'enfant, certaines particularités tant cliniques qu'histologiques rendent leur étude pleine d'intérêt. La place de la radiologie y est primordiale, en raison du caractère trompeur, non univoque du tableau clinique, en raison aussi de la fréquence des signes probants sur les clichés simples.

Nous étudions sous le terme de tumeur médullaire toutes les néoformations développées aux dépens de la moëlle, et de ses enveloppes méningées ou osseuses, à l'exclusion toutefois des tumeurs osseuses franchement métastatiques et des localisations médullaires secondaires de tumeurs cérébrales (épendymomes, médulloblastomes). De même, nous éliminons du cadre de cette étude les lipomes, ou les formations kystiques tératoïdes qui accompagnent parfois une spina-bifida ou une diastématomyélie.

Nous disposons de 18 observations. Nos patients sont tous âgés de moins de 16 ans, ou atteignent leur 17ème année. Nous n'avons retenu que les malades pour lesquels nous avons pu réunir une documentation complète, y compris la vérification histologique. Sur le plan étiologique nous ne notons pas de prédominance de sexe. La fréquence générale des tumeurs médullaires par rapport aux tumeurs cérébrales, examinées pendant la même période, paraît de 1 : 10 environ. En fonction de l'âge, une fréquence relativement plus grande au cours de la première année est apparente.

Du point de vue anatomique nous trouvons:

Sympathoblastome	6	Méningoendéthéliome	1
Neuro-épithéliome	2	Sarcome	2
Astrocytome	2	Lipome	1
Gliome	1	Neurinome	1
Médulloblastome	1	Chondrome vertébral	1

Ces tumeurs se différencient selon leur localisation par rapport à la dure-mère en:

Tumeur intradurale	5
Tumeur extradurale	11
Tumeur à la fois extra- et intradurale	2

En conclusion de cette étude anatomique, retenons la fréquence des tumeurs malignes comparativement à ce que l'on observe chez l'adulte, la fréquence également des sympathoblastomes.

Sur le plan clinique, nous avons fait les mêmes constatations que tous ceux qui avant nous se sont attachés au même problème. Le tableau clinique est exceptionnellement évocateur d'emblée; cette remarque est d'autant plus valable que l'enfant est plus jeune et peu coopérant. Ceci constitue un facteur de gravité car les troubles évoluent souvent pendant longtemps avant que le diagnostic exact ne soit posé. Selon la rapidité d'installation, et le caractère de la symptomatologie, les diagnostics évoqués peuvent être: myélite transverse aiguë, syndrome de Guillain-Barré, poliomyélite ou séquelle de poliomyélite, mal de Pott, scoliose congénitale ou acquise, voire hystérie.

Si l'on arrive au diagnostic, il devient souvent difficile, par la simple clinique de préciser la hauteur exacte de la tumeur.

Des arguments de valeur peuvent être fournis par l'étude du liquide céphalo-rachidien; nous n'y insisterons pas. Nous voulons par contre porter toute notre attention sur l'aide considérable apportée au diagnostic par la radiologie. L'étude radiologique dans de tels cas comporte d'abord un examen standard de tout le rachis. Si le diagnostic se confirme, une myélographie sera pratiquée avant l'intervention.

L'examen radiologique simple doit respecter pour être valable certains impératifs:

Etudier le rachis dans son entier.

Multiplier les incidences: face, profil, et obliques sont nécessaires.

Obtenir des clichés bien centrés sur chaque région étudiée.

Pouvoir analyser parfaitement les structures osseuses aussi bien que les parties molles. Cette nécessité conduit souvent à faire deux fois la même incidence avec des pénétrations différentes.

Des coupes tomographiques limitées aux régions suspectes sur les clichés simples, aideront, si besoin, à analyser les anomalies radiologiques.

Le respect de ces précautions techniques augmente notablement le pourcentage des examens positifs. Chez nos 18 sujets, l'étude radiologique simple nous a apporté des renseignements plus ou moins complets dans 16 cas. Nous analyserons maintenant brièvement ces anomalies radiologiques.

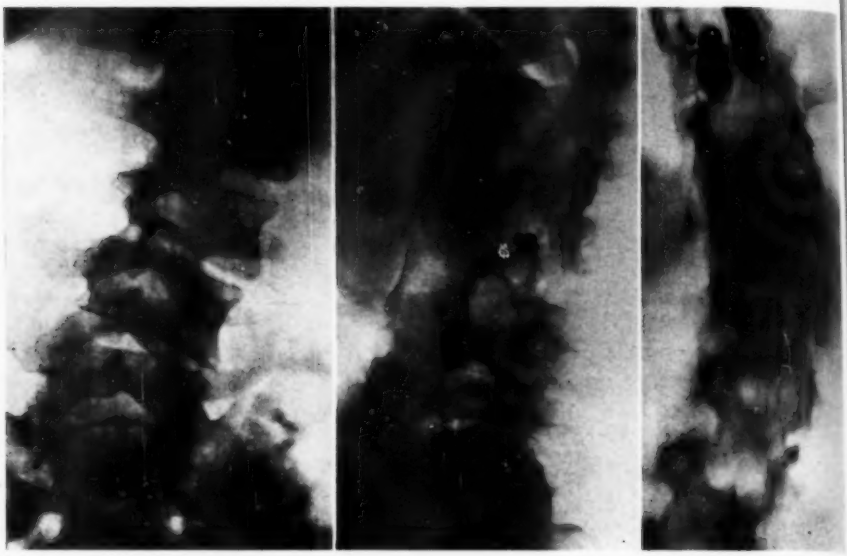

Fig. 1. Hyperlordose lombaire avec scoliose. Elargissement du canal rachidien avec érosion des pédicules, des corps vertébraux dont le bord postérieur devient concave. Elargissement des trous de conjugaison. Myélographie: arrêt en D11. Neurinome géant.

1. Modifications de la statique rachidienne. Elles ont été notées dans 14 cas. Cyphose dorsale, perte de la lordose normale lombaire ou cervicale ont été observées dans 7 cas. Une scoliose, associée ou non à l'un des troubles précédents existait dans 10 cas.

2. Elargissement du canal rachidien. Il s'apprécie de profil et surtout de face. Tantôt il est évident; tantôt simplement discret, il n'est objectivé que par l'étude de la distance interpédiculaire sur le cliché de face. Encore faut-il savoir tenir compte des élargissements physiologiques du canal rachidien. Aussi est-il utile de disposer d'une échelle fournissant en fonction de l'âge, les distances interpédiculaires moyennes selon la région du rachis envisagée.

Nous avons pu faire la preuve d'une telle anomalie chez 8 de nos 18 patients.

3. Anomalie de structure ou de forme de certaines pièces vertébrales. Dans un cas de chondrome de la troisième vertèbre cervicale il existait une image anormale de l'arc postérieur et de l'apophyse transverse gauches, point d'implantation d'une tumeur pédiculée s'extériorisant sous les parties molles latéro-vertébrales gauches.

Fig. 2.

Fig. 3.

Fig. 2. Cyphose lombaire. Elargissement du canal rachidien de D12—L4. Concavité du bord postérieur de L1—L4. Erosion et dislocation des arcs postérieurs. Fuseau prévertébral de D12—L4. Enorme tumeur extradurale débordant en avant vers la cavité abdominale. Neuroépithéliome.

Fig. 3. Sympathoblastome juxta-vertébral gauche en sablier de D2—D4.

Dans un cas de sympathoblastome en sablier, il existait en regard de la tumeur un corps vertébral condensé et aplati en galette (vertebra plana du type Calvé). Il nous a été impossible de préciser s'il s'agissait d'un envahissement tumoral, ou d'une nécrose ischémique par compression des vaisseaux du corps vertébral (comme le fait a été signalé par certains auteurs).

L'érosion, l'aspect concave du bord postérieur d'un ou plusieurs corps vertébraux en regard de la tumeur a été observé dans 4 cas (3 tumeurs extradurales et une tumeur à la fois extra- et intradurale).

L'aplatissement, l'érosion des pédicules, parfois même des lames ont été notés dans 3 cas de tumeur extradurale. Chez l'un, âgé de 6 mois, il existait en outre un important diastasis des synchondroses unissant les différents éléments de la vertèbre.

Un élargissement d'un ou plusieurs trous de conjugaison a été observé dans 8 cas de tumeur extradurale.

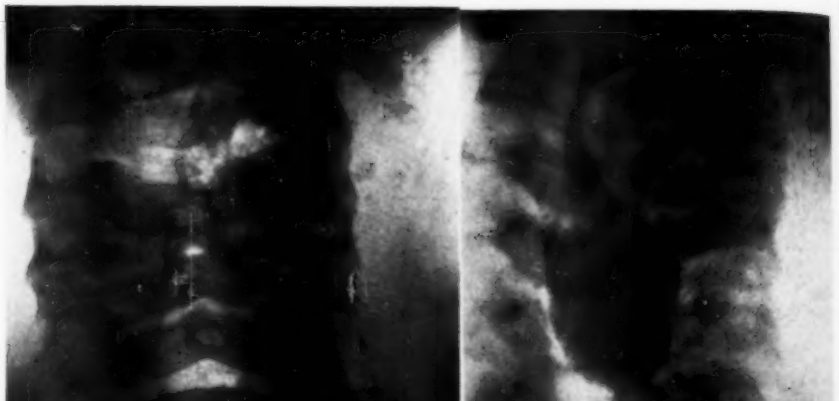

Fig. 4. Chondrome développé sur l'arc postérieur de C3 du côté gauche.

4. Tumeur en sablier. Une masse tumorale plus ou moins volumineuse développée dans les parties molles juxta-rachidiennes accompagnait 7 fois l'élargissement du trou de conjugaison. Dans un cas, la tumeur latéro-vertébrale était visible sur les clichés, mais son prolongement dans le canal rachidien n'avait pas déterminé d'aggrandissement du trou de conjugaison.

Lorsqu'il existe une tumeur en sablier, la portion extra-rachidienne peut être de volume variable: tantôt simple fuseau pré- ou latéro-vertébral; tantôt tumeur arrondie, nettement convexe de la taille d'une noix ou d'une orange, siégeant dans la gouttière latéro-vertébrale; tantôt très volumineuse, occupant la presque totalité d'un hémithorax.

Dans 3 cas, cette masse était semée de calcifications; il s'agissait dans chacun de ces cas d'un sympathoblastome.

Dans 6 cas la tumeur extra-rachidienne déterminait des anomalies du squelette costal: subluxation et refoulement en haut et en dehors de la tête costale; élargissement d'un ou plusieurs espaces intercostaux; érosion de l'arc postérieur d'une ou plusieurs côtes.

Telles sont, brièvement analysées, les différents anomalies radiologiques observées sur les clichés simples ou les tomographies.

Il faudrait, pour être complet, étudier le groupement de ces signes en fonction de la nature anatomique de la tumeur. C'est ce que nous avons tenté, et sans entrer dans les détails, il ressort de cette étude que les tumeurs intramédullaires déterminent en règle des signes osseux très discrets; les tumeurs en sablier, par contre, sont à l'origine des images les plus anormales.

Il nous reste à étudier les renseignements fournis par la myelographie. Nous n'y insisterons pas car ils sont en tous points identiques à ceux que l'on obtient chez l'adulte.

Le produit opaque (2 cc de disco-lipiodol, substance analogue au myodyl) est injecté soit par voie lombaire, soit par voie sous-occipitale soit par l'une et l'autre voies. Le transit de la bille opaque est attentivement surveillé en radioscopie. Les images d'arrêt, total ou partiel, sont fixées immédiatement grâce à un sélecteur. Cet examen, fait la veille ou le jour de l'intervention, a surtout pour but de préciser le siège exact de la compression, l'étendue de la tumeur en hauteur.

Dans 16 des cas où nous l'avons pratiquée, la myélographie a révélé: 11 fois un arrêt total; 5 fois un arrêt passager, incomplet avec refoulement de la colonne opaque par la tumeur.

Si cette étude permet d'apprécier le siège de la lésion, en règle elle ne permet pas, sur les images lipiodolées seules de préciser la nature intra- ou extramedullaire avec suffisamment de rigueur. Pour y parvenir il importe de confronter les résultats de la myélographie, de l'examen radiologique simple et de l'examen clinique.

RÉSUMÉ

L'étude souligne avant tout la fréquence des anomalies rachidiennes décelables par un examen radiologique simple dans les tumeurs médullaires de l'enfant. Sans tenir compte des troubles de la statique rachidienne, des signes radiologiques directement en rapport avec la tumeur ont été trouvés dans une proportion de 15 sur 18. C'est là un fait très particulier à l'enfant. Comparativement aux chiffres notés chez l'adulte, ce pourcentage est considérable et justifie la place primordiale de la radiologie dans le diagnostic des tumeurs médullaires de l'enfant.

SUMMARY

The study indicates in particular the high incidence of spinal changes demonstrable by conventional roentgenography in spinal cord tumours in children. Apart from disturbances of spinal function, roentgen findings in direct relation with the tumour were found in 15 out of 18 cases. This is peculiar to this age group; as compared to the rates in adults, the percentage is large and accounts for the predominant role of radiology in the diagnosis of tumours of the spinal cord in children.

ZUSAMMENFASSUNG

Die Studie betont vor allem die hohe Frequenz spinaler Veränderungen, welche durch Skelettröntgenuntersuchungen in Fällen mit Rückenmarktumoren bei Kindern demonstriert werden können. Röntgenologische Befunde, welche in direkter Beziehung zum Tumor stehen, wurden in 15 von 18 Fällen gefunden; ausserdem wurden Störungen der Statik des Rückgrates beobachtet. Diese Befunde findet man ganz besonders in der Kindheit. Im Vergleich zu den Verhältnissen im Erwachsenenalter, ist der Prozentsatz der positiven Befunde gross und erklärt die dominierende Rolle, welche die Röntgenuntersuchung bei der Diagnose von Rückenmarktumoren im Kindesalter spielt.

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STUDIES IN THE DYNAMICS OF THE SPINE

by

Jan Jirout

It is generally known that there is no reliable correlation between the degree of spondylotic deformation and the intensity of radicular pain. In healthy individuals we sometimes find very pronounced signs of deforming spondylosis. On the other hand, the routine roentgen findings in a patient with severe radicular pain may be nearly normal. The ordinary roentgen examination may also show only a certain degree of degenerative process in the spinal ligaments, and accompanying skeletal reactions. It cannot serve as objective proof of subjective complaints. We therefore turned our attention to what we have called the 'dynamic' investigation of the spine, *i. e.* examinations in the extreme positions of spinal motility. For estimations of the degree of motility, lateral films of the spine in maximal flexion and extension seem to be the most convenient. They make it possible to reveal incipient disturbances of elasticity and strength of the ligaments, *i. e.* disturbances of the mutual connections between two neighbouring vertebrae.

Dynamic examination of the lumbar and cervical spine in 50 healthy subjects gave normal findings in the great majority of cases. Some slight differences from what is supposed to be normal motility in some of these cases may be held to be a sign of a certain predisposition. As a matter of fact, in several cases these healthy individuals after a lapse of time came to us again with root pain.

Dynamic examination of the spine has been performed as a routine measure in our Department since 1951. We have examined over 1,500 individuals with lumbar and cervical radicular pain and reached conclusions which form the subject of this paper.

In the cervical spine the onset of intervertebral disc degeneration manifests itself by diminution of motility between two vertebrae, *i. e.* in one dynamic segment, usually at the level of the fifth and sixth cervical vertebrae. The lesion appears primarily only in movement, in the dynamic examination, and we have, therefore, called it 'dynamic block'.

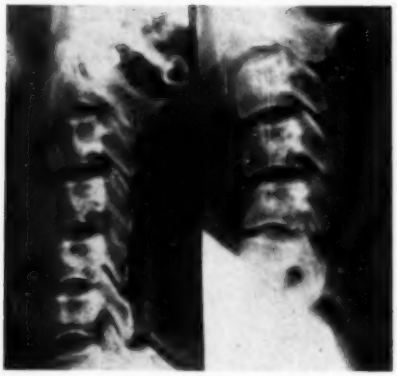

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Fig. 1. Compensatory hypermotility between C 4 and C 5. a) Upright. b) Maximum anteflexion.

This must be distinguished from 'static block' which may be detected in routine examinations and is formed by degenerative narrowing of the disc, with the vertebral terminal plates in a parallel position, or even with a slight angular kyphosis of the spine at that level.

The cervical spine is a functional entity. The diminution or loss of motility, *i. e.* the functional deficit in one segment has to be compensated elsewhere. The compensation may usually be discovered in the nearest upper segment in which the motility of the vertebrae is increased; we have called this 'compensatory hypermotility' (Figs. 1 and 2).

The effect of developmental synostosis of two or more cervical vertebrae on the spinal dynamics is similar to that of the secondary block in spondylosis deformans. It means permanent immobilisation of one or more segments, which has to be compensated. Compensatory hypermotility, and greater strain on the ligaments in the neighbouring segments, often results in very marked deformation, sclerosis, large ex-

a b c

Fig. 2. Secondary block of C 5 and C 6; compensatory hypermotility between C 4 and C 5. a) Extreme anteflexion with anterior displacement of C 4. b) Upright. c) Extreme retroflexion with posterior displacement of C 4.

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Fig. 3. Developmental synostosis of C 5 and C 6. Compensatory hypermotility of C 4 with backward displacement in extreme retroflexion (b).

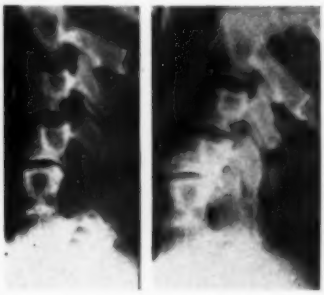

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Fig. 4. Developmental synostosis of C 5 and C 6. Compensatory hypermotility of C 4 with backward displacement in extreme retroflexion (b), and marked degeneration of intervertebral disc.

ostoses, and considerable narrowing of the vertebral interspace (Figs. 3 and 4).

If the secondary block affects the upper cervical segments, for example, the second and third vertebrae, the compensatory hypermotility appears below that segment (Fig. 5).

If the secondary block affects a dynamic segment in which normally

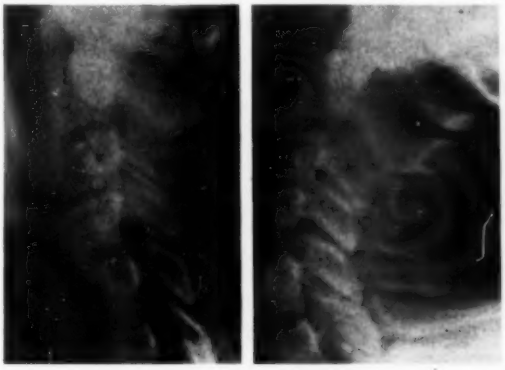

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Fig. 5. Secondary block of C 3 and C 4 with compensatory hypermotility between C 4 and C 5. Forward displacement of C 4 in anteflexion (a), and backward displacement in retroflexion (b).

Fig. 6. Secondary block of C 6 and C 7. Normal dynamics in other segments.

the movements are small, for instance between the sixth and seventh vertebrae, the disturbances of motility of the neighbouring segments may be negligible (Fig. 6). On the other hand, the blocking of a dynamic segment in which normally the motility is large (for instance, C 4—5 or C 5—6) is followed by pronounced disturbances of dynamics.

The dynamics of the lumbar spine should be investigated with the patient standing, as only this position shows the true relation between the vertebrae and disturbances of the dynamics as they appear in daily life. Disturbances of the mutual connections of lumbar vertebrae are similar to those in the cervical spine. Their principal manifestations are diminution of motility and 'compensatory hypermotility' between two vertebrae.

The degree of tension and elasticity of the intervertebral disc may be judged in extreme anterior flexion from the degree of anterior narrowing or posterior widening of the vertebral interspace (Fig. 7). In maximal posterior flexion, the degree of anterior widening and posterior narrowing of the disc are taken into consideration. The diminution of tension of the nucleus pulposus and of elasticity of the fibrous annulus in a degenerated disc allows greater approach of the margins of the vertebral bodies than under normal conditions.

Unlike the cervical spine, compensatory hypermotility of the lumbar spine presents two different forms: in anteflexion the upper vertebra moves forwards or backwards. In our opinion the condition of the nucleus pulposus is decisive; if its condition is satisfactory the vertebra is pushed backwards in anteflexion by the upper vertebrae; if the nucleus is dessicated, forward gliding is most likely to happen. In retroflexion of the spine we mostly found backward movement which was greater in those patients in whom such movement also occurred in anteflexion.

In true spondylolisthesis the degree of anterior displacement is usually constant, so that extreme flexion does not provoke any considerable changes in the mutual relation between the vertebrae. In exceptional cases where the nucleus pulposus was in good condition we found that the displaced vertebra moved backwards and took up its normal position (Fig. 8).

The above-mentioned signs of functional disturbance of the spine appear simultaneously with the clinical signs. They are therefore more important than osseous reactive changes which appear relatively late.

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Fig. 7. a) Extreme anteflexion. Dynamic block of L 4 and L 5 and forward displacement of L 3 with considerable anterior narrowing of vertebral interspace. b) Upright. Only narrowing of L 4—L 5 interspace.

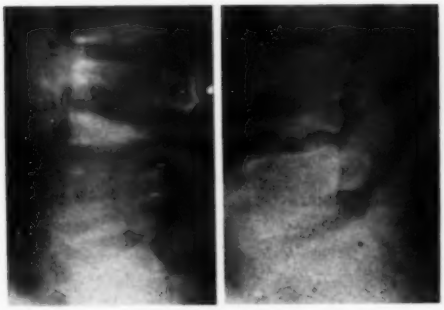

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Fig. 8. Spondylolisthesis of L 5. Backward gliding of L 5 in extreme anteflexion (a), and considerable narrowing of fissure of vertebral arch.

Their importance is increased by the fact that they may be found even before radicular pain occurs. We are now carrying out systematic investigations of spinal dynamics, in groups of healthy subjects of different ages. Our aim is to investigate variations within the physiologic limits and the age at which the disturbances of spinal motility most frequently occur. These facts are considered to be of the utmost importance, especially from the standpoint of the prevention of radicular syndromes.

SUMMARY

Various roentgenologic signs of disturbances of connection between two neighbouring vertebrae are dealt with. The 'dynamic' examination of the cervical and lumbar spine shows diminution of motility and/or 'compensatory hypermotility', often simultaneously with the onset of radicular pain, sometimes even before. Its importance in early diagnosis, and from the standpoint of prevention of radicular syndromes is stressed.

ZUSAMMENFASSUNG

Verschiedene röntgenologische Befunde bei Störungen des Konnexes zwischen 2 benachbarten Wirbeln werden besprochen. Die »dynamische« Untersuchung der Hals- und Lendenwirbelsäule zeigt eine Abnahme der Beweglichkeit und/oder »kompensa-

torische Hypermotilität«, oftmals gleichzeitig mit dem radikulären Schmerzanfall, manchmal auch vor diesem. Ihre Bedeutung für die Frühdiagnose und für die Vermeidung der radikulären Syndrome wird hervorgehoben.

RÉSUMÉ

Divers signes radiologiques d'altération des rapports entre deux vertèbres voisines sont envisagés. L'examen «dynamique» de la colonne cervicale et lombaire montre une diminution de la mobilité et/ou une «hypermobilité compensatrice», apparaissant souvent en même temps que le début de la douleur radiculaire, et même la précédant quelquefois. L'auteur souligne son importance pour le diagnostic précoce et du point de vue de la prévention des syndromes radiculaires.

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FROM THE ROENTGEN DEPARTMENT (DIRECTOR: PROF. ERIK LINDGREN), SERAFIMERLASARETTET, STOCKHOLM, SWEDEN

THE ANATOMY OF THE SUBARACHNOID CISTERNS

by

B. Liliequist

Encephalography has become more and more widely used in recent years. As a result of this development, we have learned that the investigation of the subarachnoid cisterns is often just as important as that of the ventricular system. Encephalography gives more information than ventriculography, and examinations of the latter type have therefore decreased in number at Serafimerlasarettet. The anatomy and roentgenographic appearances of the cisterns are not as well known as those of the ventricular system. The anatomy has, to be sure, been described in the anatomic literature, but the descriptions have been written in such a manner that they are not immediately useful when it comes to the orientation of the structures in the roentgen film. We have also found the roentgenologic descriptions of the cisterns, available in the literature, to be incomplete and partly incorrect. Comparative studies of their appearances in anatomic specimens and in roentgen films have therefore been carried out.

The brains used for the anatomic investigations were previously fixed with formaldehyde injected intra-arterially. A solution of gelatine in water, into which barium sulphate had been stirred, was used as contrast medium and was injected either into the cerebello-medullary cistern or into the subarachnoid space above the quadrigeminal plate. The injection was made and the roentgen films were exposed before the cranial vault was opened. The brain was then removed and additional films were obtained, mainly in the projections common in encephalography. At this stage, tomography was also used. The appearances of the cisterns in these films and in dissections of the specimens have been compared with a large number of normal encephalographies. The following report refers only to the appearances of the cisterns in adults.

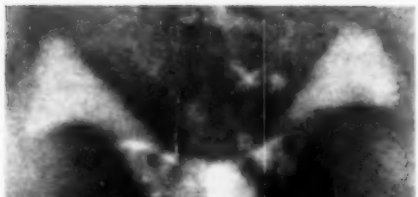

Fig. 1. Air in medullary cistern, and extensions from cerebello-medullary cistern delimiting the medulla oblongata. The trigeminal nerve is seen as a round soft tissue formation in medial part of cerebello-pontine cisterns.

The cerebello-medullary cistern is situated in the angle between the medulla oblongata and the cerebellum. The subarachnoid space in front of the medulla oblongata constitutes the medullary cistern. The pontine cistern lies in front of the pons, and is continued superiorly in the intercrural cistern and anteriorly in the chiasmatic cistern. The cistern of the lamina terminalis is in front of the third ventricle and merges into the cistern of the corpus callosum. The quadrigeminal plate gives the cistern above its characteristic radiologic appearances, and we therefore call it the quadrigeminal cistern; it is also known as the cistern of the great vein of Galen. The cerebello-medullary cistern merges above the vermis into the subarachnoid space, which is very narrow. The cistern continues forwards into the vallecula, situated between the tonsils into which the foramen of Magendie also opens. Anteriorly, the cerebello-medullary cistern communicates on each side with the medullary cistern; these communications appear in frontal views taken with a beam direction approximately parallel to the clivus as two oblique rather narrow bands of air (Fig. 1). The air in these situations together with the air in the medullary cistern delimits the medulla oblongata in the roentgenogram. Around the tonsils the cerebello-medullary cistern also communicates antero-superiorly with the pontine cistern, opening into it approximately at the point where it merges into the cerebello-pontine cistern.

On both sides of the pons, the pontine cistern communicates through a broad passage with the cerebello-pontine cistern, situated in the angle between the pons and the cerebellum. Anteriorly, it is limited by the posterior surface of the pyramid, posteriorly by the anterior surface of the cerebellum, and superiorly by the tentorium (Fig. 2).

The contour between the air in the cerebello-pontine cistern and the surface of the cerebellum is always irregular. Medially and antero-inferiorly, the cistern is delimited by the convex lateral surface of the pons. A round, soft tissue formation surrounded by air may be seen in the cistern in films taken with less tilt of the tube than employed for the usual half-axial view; this is caused by the trigeminal nerve. It is highly im-

portant that radiologists should be familiar with the normal appearance of these cisterns, since tumours situated in the pontine angle often deform the cisterns before they affect the appearances of the ventricular system.

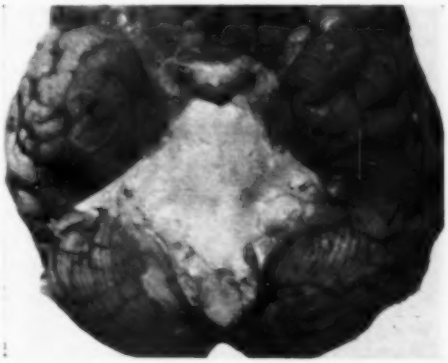

Fig. 2. Barium contrast in pontine and cerebellopontine cisterns showing the broad passage between them.

A large subarachnoid space is situated between the anterior surface of the pons and the medial portions of the posterior surface of the frontal lobes. Its lateral limits consist of the medial surfaces of the temporal lobes. The Sylvian fissure issues laterally from both sides of its anterior part. This subarachnoid space is generally divided into two cisterns, one lying postero-superiorly — the intercrural cistern — and the other antero-inferiorly — the chiasmatic cistern. There is no commonly accepted limit between the two; DAVIDOFF and DYKE described it as follows: "The interpeduncular cistern extends as far anteriorly as the caudal margin of the optic chiasm and the internal carotid arteries." There is, however, a thin arachnoidal membrane in this subarachnoid space. This membrane is often seen in the encephalogram as a fine line with a convexity forwards, extending from the tip of the

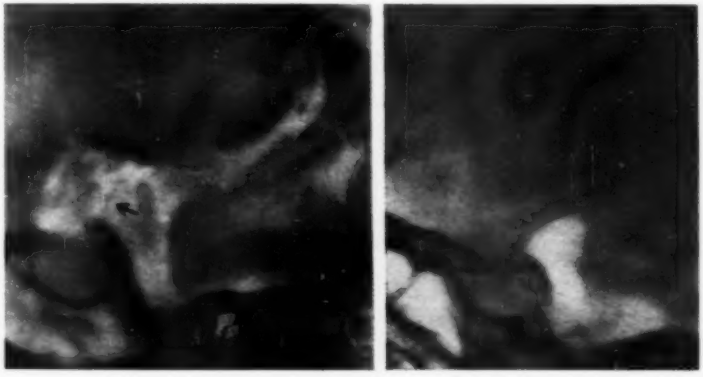

Fig. 3. Membrane separating intercrural and chiasmatic cisterns (*left*). Air arrested against the membrane (*right*).

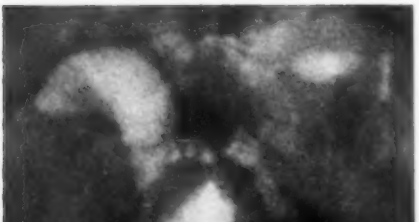

Fig. 4. Crural cisterns of characteristic appearance.

dorsum of the sella to the anterior edge of the mamillary bodies (Fig. 3). In our opinion, this membrane is probably the reason why often during encephalography the air at first remains in the intercrural cistern, and only gradually fills the chiasmatic cistern. It seems appropriate to accept this membrane as the line of demarcation between the chiasmatic and the intercrural cisterns, possessing as it does the advantages of a definite anatomic structure. If the membrane cannot be seen, the limit may be denoted by a line from the tip of the dorsum of the sella to the anterior edge of the mamillary bodies, or, in other words, approximately a straight line from the tip of the dorsum of the sella perpendicular to the upper border of the cistern.

The intercrural cistern covers the intercrural fossa and continues below and laterally to the cerebral peduncles. Its lateral extensions, from a practical point of view, should have their own name, since they may cause certain diagnostic difficulties. We call them the crural cisterns (Fig. 4). A small part of the uncus is situated in the cistern medially to the edge of the tentorium.

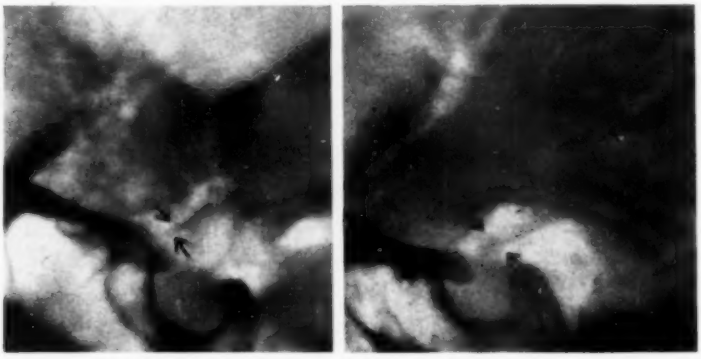

Fig. 5. The optic chiasm can be located either in front of and on the same level as the anterior clinoid processes (*left*), or behind them (*right*).

The intercrural cistern communicates anteriorly with the chiasmatic cistern, which is largely filled by the optic chiasm and the two internal carotid arteries, and antero-laterally merges into the Sylvian fissure. If these two cisterns are observed from the side in a specimen, they will present an almost square appearance. Anteriorly, the chiasmatic cistern is in relation to the posterior edge of the gyrus rectus on the lower surface of the frontal lobe, except in the midline where the cistern communicates with the cistern of the lamina terminalis.

Fig. 6. The basilar artery in a p. a. film.

The anterior contour of the chiasmatic cistern is generally softly rounded with a convexity backwards. The roof of the cistern is roughly straight. Sometimes the cistern in front of the chiasm is not filled with air, the air remaining instead against the posterior surface of the chiasm. This must not be confused with the situation which develops when the air is arrested by the membrane separating the chiasmatic and the intercrural cisterns. The posterior surface of the chiasm is straight whereas the membrane always is slightly curved. The relation between the position of the chiasm and the

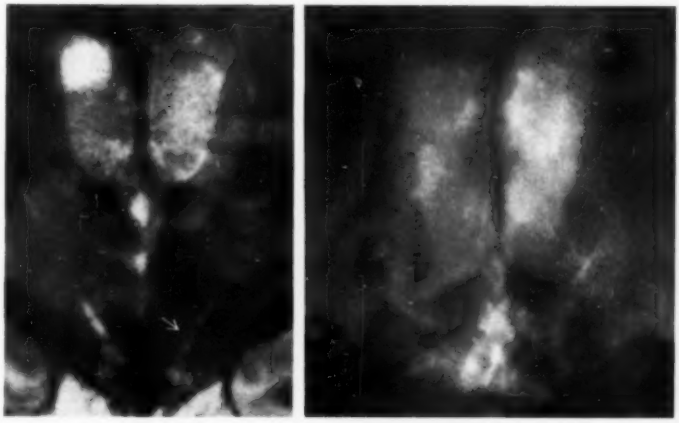

Fig. 7. The olfactory cisterns (*left*) are situated closer to the midline than the crural cisterns (*right*).

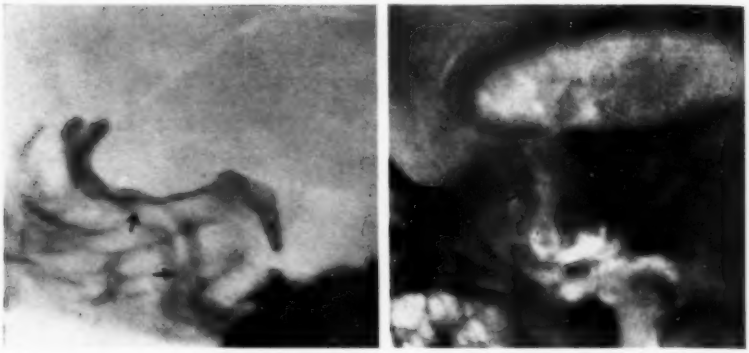

Fig. 8. Specimen with contrast medium surrounding the pericallosal artery which passes across the gyri and sulci (*left*). Air around the pericallosal artery simulating a subfrontal tumour (*right*).

anterior clinoid processes differs. The lower forward part of the chiasm is either situated in front of the tip of the anterior clinoid processes, on a level with them, or behind them above the sella (Fig. 5). Furthermore, the infundibulum, the tuber cinereum, and the mamillary bodies, are visible in the cistern. The posterior limit for the air in the intercrural cistern consists of the anterior surface of the pons. In the posterior part of the cistern the basilary artery is always visible; it may be seen in frontal views (Fig. 6).

The intercrural cistern is situated between the cerebral peduncles and the crural cistern on both sides of the peduncles. The latter have a characteristic appearance, and can always be identified. They are pointed, and diverge superiorly and laterally. The limits of the crural cistern consist laterally of the uncus, medially of the cerebral peduncles, and superiorly of the optic tract. Postero-inferiorly, they merge into the ambient cistern. The air in the crural cistern is situated on a level which lies more anteriorly and higher up than the air around the rest of the brain stem, that is, in the ambient cistern.

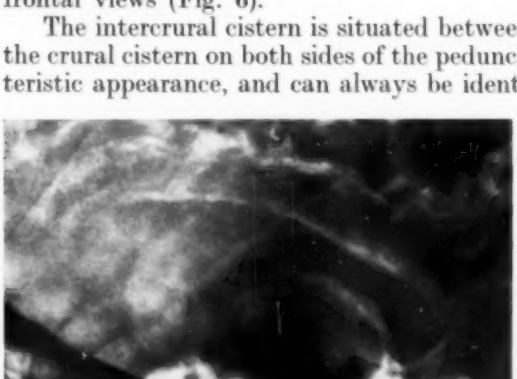

Fig. 9. Cistern of corpus callosum.

Fig. 10. Specimen with contrast medium in the quadrigeminal cistern, aqueduct and fourth ventricle.

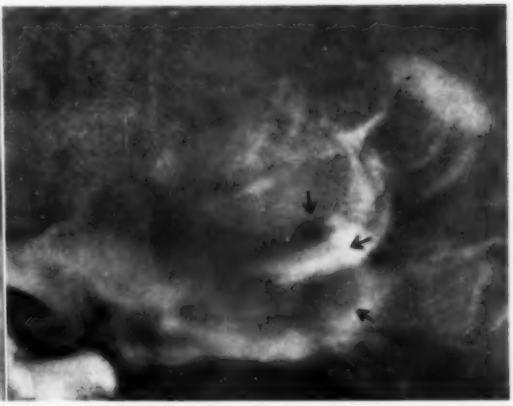

Fig. 11. The quadrigeminal plate is easily discernible on a lateral view.

These two levels of air may therefore always be seen to cross in such a view. The appearances of the crural cistern are such that they might be confused with a cerebello-pontine cistern displaced upwards. This may occur particularly if the crural cistern is filled without filling of the cerebello-pontine cistern. One may thus make the mistake that there is a soft tissue mass displacing the cerebello-pontine cistern. The two cisterns are situated on two different levels and may thus be separated in films exposed with different beam directions.

From the most anterior part of the chiasmatic cistern, extensions of the subarachnoid space — the olfactory cisterns — continue on each side of the midline into the olfactory sulcus. The best filling is obtained with the patient in the supine position. In an a. p. film they look somewhat like the crural cisterns, but diverge less and are situated closer to the midline. In a half-axial a. p. film the crural cisterns, but not the olfactory cisterns, may be seen (Fig. 7). There should thus be no difficulty in practice to differentiate between the two cisterns.

Fig. 12. The quadrigeminal plate in a p. a. film.

The chiasmatic cistern continues an-

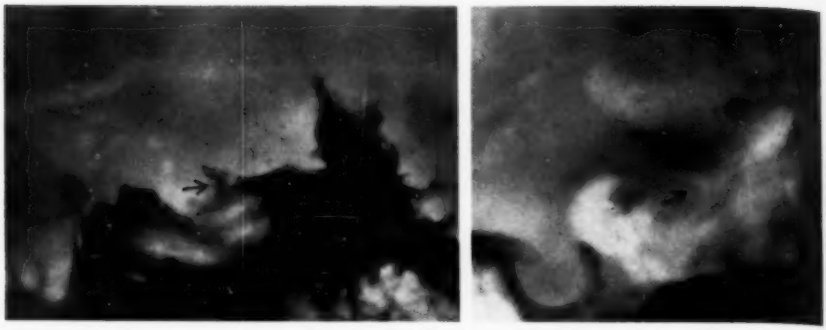

Fig. 13. The ambient wings end against uncus. Contrast medium in the wings (*left*); air in the wings (*right*).

tero-superiorly along the midline as the cistern of the lamina terminalis. It merges above into the cistern of the corpus callosum at the point where the genu of the corpus callosum commences. This provides an otherwise lacking, sharply defined anatomic limit between the cistern of the lamina terminalis and the cistern of the corpus callosum. Air is often present also in the other sulci on the medial surface of the frontal lobes. The first part of the pericallosal artery commonly passes right across the sulci and gyri in a slight curve, and air may then be present in the subarachnoid space surrounding the artery. This string of air then has the same form, that is, concave antero-inferiorly, and may appear similar to the air surrounding a subfrontal extracerebral tumour (Fig. 8).

The cistern of the corpus callosum surrounds the corpus callosum, and may be divided into three parts — the anterior part surrounding the genu, the middle or upper part above the corpus, and the posterior part around the splenium. Like the pericallosal artery, the posterior portion of the latter sometimes describes an arc with a slight downward convexity (Fig. 9). Around the splenium the posterior part communicates with the quadrigeminal cistern.

The quadrigeminal cistern is situated in the posterior part of the tentorial notch (Fig. 10). The colliculate bodies, the anterior medullary velum, and the lingula cerebelli, form its inferior relations and the vermis, the anterior edge of which is slightly convex, its posterior relation; the main part of the roof consists of the splenium. The pineal body bulges into the anterior part of the cistern, and the great vein of Galen is situated in its upper part. Its width is the same as that of the quadrigeminal plate. It merges laterally into the ambient cistern. The cistern communicates anteriorly with the subarachnoid space above the third ventricle and posteriorly with the subarachnoid space surrounding the vermis of the cerebellum.

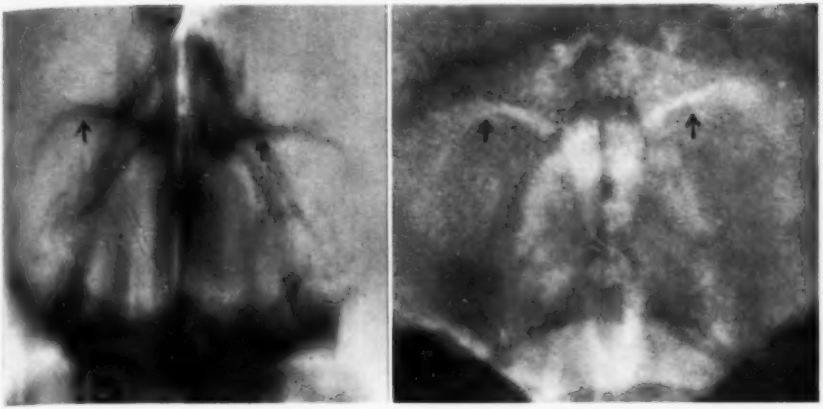

Fig. 14. The ambient wings above thalamus filled with contrast medium (*left*) and with air (*right*).

The appearance of the quadrigeminal plate is so characteristic that it is easy to recognize, and this gives us also the position of the cistern (Fig. 11). Below the splenium the cistern is largely filled by the great vein of Galen. When the aqueduct and the fourth ventricle also are filled with air, it is possible to estimate the form and thickness of the quadrigeminal plate, the anterior medullary velum, and the lingula cerebelli. The quadrigeminal plate is easily discernible against the air in a frontal view (Fig. 12). A rounded formation may often be seen in the cistern between the colliculate bodies; it consists of the pineal body and the great vein of Galen projected on top of each other.

The ambient cistern is a twofold cistern surrounding the brainstem. It issues posteriorly from the quadrigeminal cistern, turns round the brainstem, and communicates anteriorly with the pontine and crural cisterns. It is thus much narrower posteriorly and extends forward in a fan-like manner; its greatest extension is in the sagittal plane. The larger part of the cistern is situated below the tentorium and the smaller part above it.

Two arched bands of air crossing the quadrigeminal plate are often seen in lateral films. They either cross the anterior or the mid-section of the quadrigeminal plate, but never behind it. These arcs have been thought by most authors to indicate the ambient cistern. Anatomic investigation shows, however, that this part of the subarachnoid space is situated around the thalamus, is perpendicular to the ambient cistern proper, and extends from its antero-superior edge; a good name for it would be the wing of the ambient cistern. These wings are situated in the frontal plane. They continue above the thalamus and below the for-

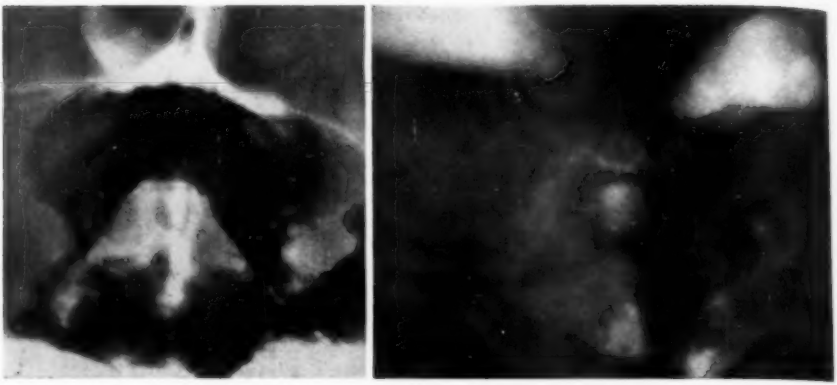

Fig. 15. Appearance of ambient wings in a p. a. film, filled with contrast medium (*left*), and with air (*right*).

nicis as far as the foramen of Monroe. Laterally the wings extend to the attachment of the chorioid plexus. There is thus a narrow subarachnoid space stretching laterally to the medial wall of the temporal horn and separated from it only by a thin layer of pia and ependyma. The wings communicate above the roof of the third ventricle with each other, and behind the thalamus with the quadrigeminal cistern. The walls consist on the anterior concave aspect of the thalamus, on the posterior convex aspect of the fornix, and inferiorly of the hippocampal gyrus. The wing terminates anteriorly against the posterior edge of the uncus (Fig. 13).

In frontal projections the layer of air in the wings is narrow and they are therefore difficult to observe; the air lying around the top of the thalamus is, however, often seen in the form of the two narrow bands (Fig. 14).

In a specimen with contrast medium in the cisterns, these wings have a characteristic appearance. Sometimes, when the subarachnoid space in the wings is wider than usual, it is possible to see the wings air-filled in a p.-a. film (Fig. 15).

It will be evident from this description that different parts are seen in lateral and frontal views. This is due to the position of the ambient cistern proper and its extensions, the ambient wings. The former can thus only be seen in frontal projections, and the ambient wings essentially only in lateral views.

The investigation of the subarachnoid space has achieved great importance and in the future, probably, it will become even more valuable in the early diagnosis of intracranial expanding lesions. This, however, presupposes an exact knowledge of its normal anatomy.

SUMMARY

The anatomic and roentgenologic appearances of the subarachnoid cisterns, based upon comparative studies, are described.

ZUSAMMENFASSUNG

Das anatomische und röntgenologische Aussehen der subarachnoidalen Cisternen wird beschrieben; der Verfasser stützt sich hierbei auf komparativen Studien.

RÉSUMÉ

Se basant sur des études comparatives, l'auteur décrit les aspects anatomïques et radiologiques des citernes sous-arachnoïdiennes.

FROM ST. GEORGE'S HOSPITAL AND THE NATIONAL HOSPITAL FOR NERVOUS DISEASES, LONDON, ENGLAND

THE NORMAL VARIATIONS IN THE POSITION OF THE OPTIC RECESS OF THE THIRD VENTRICLE

by

James Bull

The real purpose of this paper is to define the position of the optic chiasm. It is not easy to demonstrate this structure radiologically, but we know that its upper and posterior border is attached to the optic recess of the third ventricle. It is therefore easy to pin-point the chiasm at pneumography.

Previous anatomic studies. In 1924 SCHAEFFER stated "At first thought it may appear strange that so important and conspicuous a structure as the optic chiasm should be subject to gross mis-statements concerning its location". He went on to quote modern text books of that time which described the chiasm as lying on the optic groove (sulcus chiasmaticus).

SCHAEFFER studied 125 freshly exposed brains and very clearly recorded his findings in his well known diagram (Fig. 1).

Since anatomic relations may be disturbed even in fresh brains, one felt that an attempt should be made to confirm Schaeffer's findings in life, as apparently no such attempt has been made before.

Furthermore it does not seem amiss to reiterate Schaeffer's comments of 30 years ago, for the 1954 Edition of Gray's Anatomy states "Inferiorly the chiasma *rests* (my italics) on the diaphragma sellae just behind the optic groove of the sphenoid bone and thus in close relation to the hypophysis cerebri". It would appear from this text and the illustrative figure that no allowance is made for variations in the position of the chiasm or any space provided for the chiasmatic cistern.

ZANDER (1896) made it quite clear that the shape and relations of anatomic structures close to the optic chiasm vary very much. For example on examining 100 skulls he found that only 34 had a sulcus

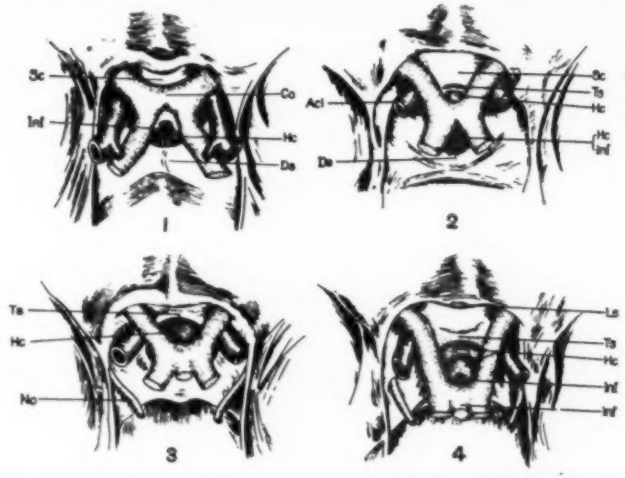

Fig. 1 (from original of Fig. 1, J. P. SCHAEFFER, Anat. Rec., **28**: 253). 1. Optic chiasma located in part on the chiasmatic sulcus, the remaining portion resting upon the diaphragma sellae. (5 % of the bodies examined.) 2. Optic chiasma wholly located over the diaphragma sellae. (12 % of the bodies examined.) 3. Optic chiasma almost wholly located over the diaphragma sellae, a small portion projecting on to the dorsum sellae. (79 % of the bodies examined.) 4. Optic chiasma located on and behind the dorsum sellae. (4 % of the bodies examined.) *Sc*, sulcus chiasmatis; *Inf*, infundibulum; *Co*, chiasma opticum; *Hc*, hypophysis cerebri; *Ds*, dorsum sellae; *Aci*, arteria carot. int.; *Ts*, tuberculum sellae; *No*, nervus oculomotorius; *Ls*, limbus sphenoidalis.

chiasmaticus. Being aware that the chiasm did not lie upon the sulcus, even when it was present, and of the confusion caused by this terminology he wished to rename it the 'area praesellaris'. Among other important observations he noted that the distance between the medial walls of the optic foramina varied by as much as from 20 to 11.5 mm. Following upon this he further noted that the optic nerves diverge forward from the chiasm at different angles depending on the length of the nerves and the interforaminal distances, and the angle was usually less than a right angle. For the angle to be so small it was necessary for the intracranial length of the optic nerves to be greater than was supposed before Zander's time. He found that the length of this portion of the nerves varied between 21 mm and 6 mm.

The variable signs or even absence of signs observed by clinicians in cases presenting with suprasellar masses led one to investigate the position of the chiasm not only in antero-posterior direction but also its height above the hypophysis. Both Zander's and Schaeffer's work was limited by the fact that since anatomists handle corpses they must have had great difficulty in assessing the depth of the chiasmatic cistern.

Fig. 2 (After EUGENE WOLFF). Sagittal section of third ventricle.

Although the optic chiasm can seldom be demonstrated pneumoencephalographically, outlined as it would have to be, between the optic recess of the third ventricle and the air-filled chiasmatic cistern, the anterior end of the third ventricle can be constantly outlined.

It is an anatomic fact that the chiasm is adherent to the posterior and inferior edges of the optic recess of the third ventricle (Fig. 2).

The objection might be raised that the optic recess and thus the chiasm, moves with posture. This has been refuted by examining a few patients both with air in the supine position and with a positive contrast substance in the prone position. No movement has been detected.

Present Material

Only cases thought to be normal were used. An attempt was made to find patients of both sexes from 0 to 70 years. They were divided into five year groups 0—5, 6—10, 11—15 and so on. 5 cases from each five year group were sought. 117 out of a possible 140 cases were collected and measurements were made. The examinations were all carried out on a Lysholm skull table.

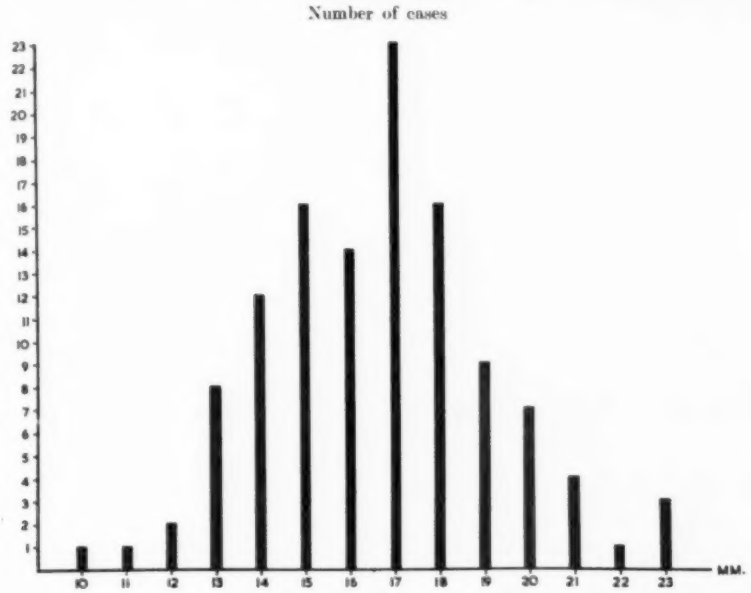

Diagram 1. Approximate lengths of intracranial portion of optic nerves as measured from chiasmal point to tuberculum sellae in lateral view.

Analysis of material. In attempting any systematic arrangement, Zander's findings of the multiplicity of variables became only too obvious.

The first difficulty encountered was the variability of the *bony* landmarks. That normal sellae vary in size and shape is well known, but the tilt of the sella and thus the height of the dorsum sellae was also found to vary. A constant base line was sought and adhered to, that joining the nasion to the tuberculum sellae being chosen. It is realised that the shape and prominence of the tuberculum sellae varies, but it has the advantage not only of representing the antero-superior edge of the hypophysial fossa, but also it can be identified quite easily on a lateral radiograph. The base line was placed horizontally in every case to allow comparisons to be made.

The *optic chiasm* was taken as a point, rather than an area which it is in fact. The point taken was that of deepest insertion of the wall of the third ventricle between the optic and infundibular recesses. This point appears not to have an anatomic name. For the remainder of this paper I will call it the 'point of chiasmatic insertion' or the 'chiasmal point'.

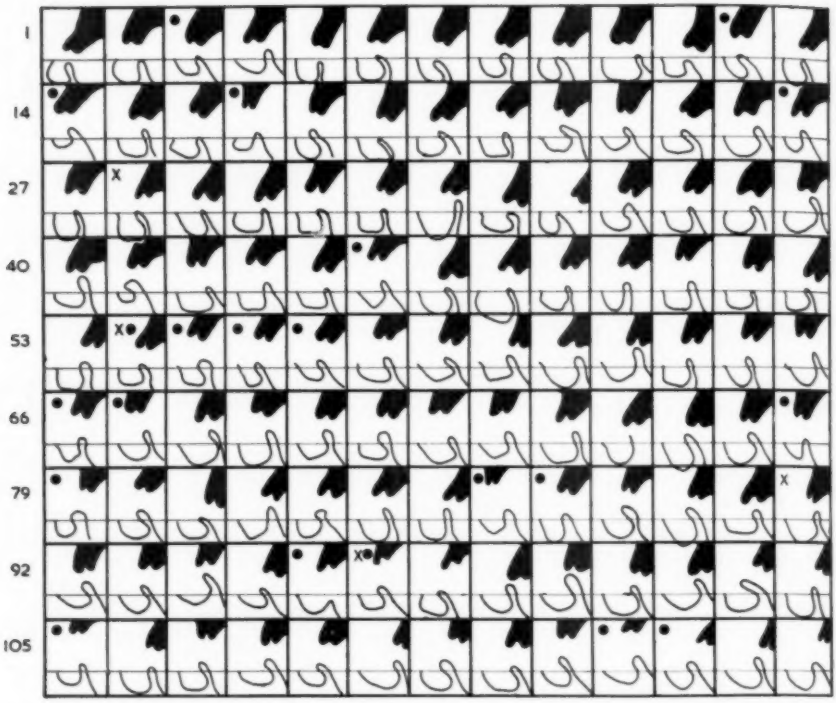

Fig. 3. Tracings of the 117 normal cases. Thin horizontal line represents the 'nasion-tuberculum sellae' plane. Note how the height of the top of the dorsum sellae varies in relation to this plane. Blacked out area in each figure represents the anterior end of the third ventricle. ● — cases under 15 years (21 cases); × — myodil in third ventricle (4 cases).

In all cases the distance from the tuberculum to the chiasmatic point was measured; it varied between 10 and 23 mm (Diagram 1) and represented, admitted slightly inaccurately (owing mainly to obliquity of the nerves and photographic enlargement), the intracranial length of the optic nerves.

In spite of the various slight corrections necessary, the measurements corresponded fairly well with Zander's findings of a variation from 21 to 6 mm. He also measured the sagittal diameter of the chiasm and found that it varied between 4 and 13 mm in 32 cases, the average being 8.04 mm. The thickest portion of the chiasm, he said, lay in the anterior part of the sagittal section.

The 117 cases were then arranged in order of length of the tuber-

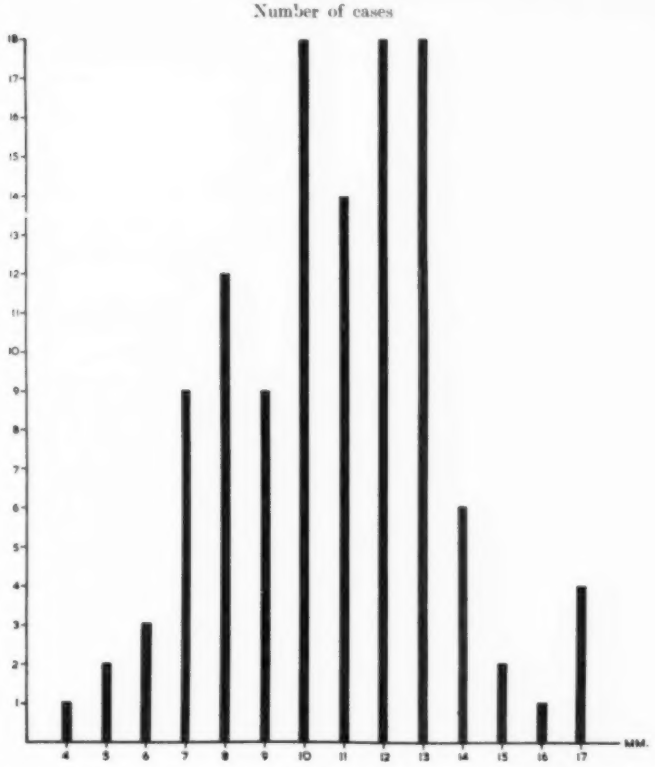

Diagram 2. Height of chiasmal point above 'nasion-tuberculum plane'.

culum to the chiasmatic point and then traced on to a diagram (Fig. 3) which gives one an overall picture of some of the variables. It shows:

1) The varying size, shape and tilt of the sella.

2) The varying height of the dorsum sellae to the base line and thus the tilt of the plane of the sella diaphragm. (The top of the dorsum sellae cannot be accurately identified. The point usually seen in a lateral radiograph is the top of one or other posterior clinoid process, or both superimposed. The top of the dorsum sellae probably lies a little below this point in most cases.)

3) The varying distance backwards of the chiasmal point relative to the tuberculum.

4) The varying distance upwards of the chiasmal point relative to the tuberculum.

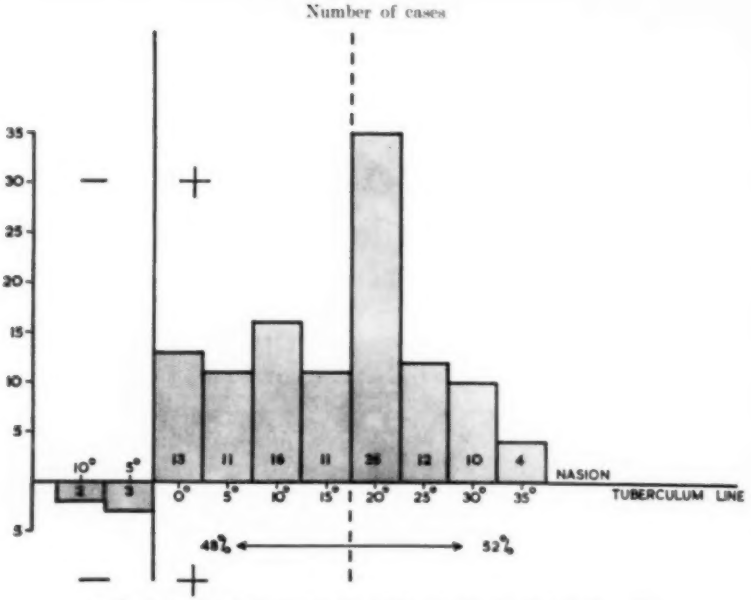

Diagram 3. 52 % of cases showed a forward tilt of the presumed sella diaphragm plane of 20° or more. Only 5 cases (4.3 %) showed a backward tilt of the sella diaphragm.

5) How 3) and 4) also give an indirect indication of the varying size and shape of the chiasmatic cistern.

In each case the height of the chiasmal point above the nasion-tuberculum line was measured. Diagram 2 shows the findings.

Discussion

It is apparent that Zander's and Schaeffer's findings are confirmed.

The tilt of the sella introduces another variable factor as far as the relation of the sella diaphragm to the chiasma is concerned. Diagram 3 analyses the varying tilt of the sella and thus presumably of the diaphragm, relative to the nasion-tuberculum line. This tilt will in turn be influenced by the height of the chiasmal point. The tilt of the plane of the optic nerves will also vary if these premises are true. Fig. 4 shows the presumed angle of the optic nerves, taken from four of the cases, as seen in lateral view. In this diagram one assumption was made — that the optic foramen bears a constant relation to the tuberculum when seen in lateral view.

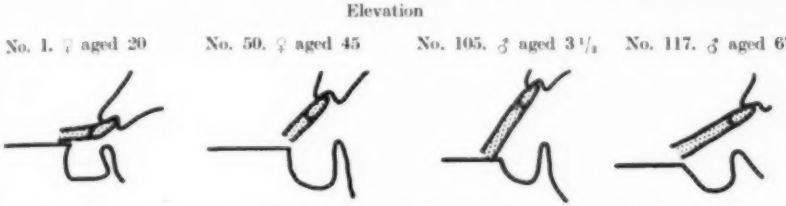

Fig. 4. Presumed angle of optic nerves in four cases, as seen in lateral view.

Clinical applications. Since there are so many anatomic variants it would hardly be surprising to find varying visual field charts for tumours of similar size in different patients. This is a fact accepted by neurologists. I suggest that tumour cases need further investigation with these points in mind.

I believe that many suprasellar masses can become much larger than is generally appreciated before signs develop. This might occur especially when there is great forward tilting of the sella combined with a long intracranial portion of the optic nerves. Fig. 5 taken from the series, is such an example, showing *(left)* the sella and third ventricle and *(right)* the envisaged growth of a pituitary tumour in such a case. It would tend to grow up in front of the chiasm before exerting any pressure. We also do not know how much splaying and stretching the optic nerves and chiasm can tolerate before an abnormal visual field can be charted.

In assessing the relationship of the sella to the chiasm it is not sufficient to consider Schaeffer's diagram alone which provides a two dimensional concept. One must also take into account the tilt of the sella and the height of the chiasmal point.

Fig. 5. Case No. 94. ♀ aged 56. *Left:* Sella and third ventricle. *Right:* Presumed direction of growth of a pituitary tumour in such a case.

Acknowledgements

I am indebted to my colleagues Mr. WYLIE MC KISSOCK and Mr. VALENTINE LOGUE for the material; to Dr. CAHILL and Dr. JAYAMANNE for help in abstracting the cases; to Mr. PRICKETT and his photographic staff at the National Hospital for Nervous Diseases for slides and prints. To all of them I wish to express my thanks.

SUMMARY

The author has examined 117 normal pneumoencephalograms, representing all age groups from birth to seventy years. The object was to assess the position of the optic recess of the third ventricle, and thus the optic chiasm. The tuberculum sellae was chosen as the reference point and it was found that the position of the optic recess varied quite considerably in its relation to the tuberculum. The variation was generally in keeping with SCHAEFFER's anatomical findings. However, SCHAEFFER's study was essentially two-dimensional and was made on the corpse, while the present study was three-dimensional and carried out in life.

ZUSAMMENFASSUNG

Der Verfasser hat 117 normale Pneumoencephalogramme untersucht, welche alle Altersgruppen von Neugeborenen bis zum 70. Lebensjahr umfassen. Die Absicht war, die Lage des Processus opticus des III. Ventrikels sowie die des Chiasma nervi optici festzustellen. Das Tuberculum sellae wurde als Referenzpunkt gewählt und man fand, dass die Lage des Recessus opticus im Verhältnis zum Tuberculum sellae ziemlich beträchtlich variierte. Die Variation stimmte im allgemeinen mit SCHAEFFER's anatomischen Befunden überein. Die Studien von Schaeffer waren jedoch hauptsächlich zweidimensional und an Leichen ausgeführt, während die vorliegende Untersuchung dreidimensional ist und am Lebenden durchgeführt worden ist.

RÉSUMÉ

L'auteur a examiné 117 pneumo-encéphalographies normales représentant tous les groupes d'âge de la naissance à soixante-dix ans. Le but était de déterminer la position du récessus optique du troisième ventricule, et ainsi, celle du chiasma optique. Le tubercule de la selle a été choisi comme point de référence; les rapports du récessus optique avec le tubercule de la selle se sont montrés très variables. Ces variations sont, en général, en accord avec les constatations anatomiques de SCHAEFFER. Cependant l'étude de SCHAEFFER est essentiellement bidimensionnelle et faite sur le cadavre, alors que la présente étude est tridimensionnelle et faite sur le vivant.

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CHANGES IN THE SIZE OF THE SUBARACHNOID SPACES AFTER THE INSUFFLATION OF AIR

by

Jan Jirout

The size of the subarachnoid spaces after insufflation of contrast media is generally supposed to be constant.

Nevertheless, experience has taught us that this supposition is unfounded. The size of cerebrospinal fluid pathways during and after pneumoencephalography changes according to the degree of oedema of the surrounding brain tissue. It is possible to influence this process by intravenous application of hypertonic solutions. Furthermore, alterations in the subarachnoid spaces produced by different positions of the head must be taken into consideration. All these changes may reach such proportions as to be clinically significant.

We have found that the size and shape of the lateral ventricles in air studies vary. The differences may best be followed in the antero-posterior supine position. The lateral recess of the ventricle often shows considerable narrowing; distinctly so on the last film obtained during pneumoencephalography, *i. e.* circa 20 minutes after insufflation of air, as compared with the first film taken immediately after the air has been introduced. To obtain correct results it is essential that the amount of air and the position of the head be the same in both (Fig. 1).

These facts may be explained by oedema of the ventricle walls caused by the irritative effect of air. Our findings agree with those writers who found marked dilatation of the ventricular system 24 hours after the introduction of air.

In review it may be stated that oedema of the ventricle walls causes diminution in the size of the ventricle immediately after insufflation, the oedema gradually subsiding in the course of some hours. Films obtained 24 hours later, therefore, show the true size and shape of the ventricles. In agreement with other authors, we have found the greatest changes in patients with a history of closed injuries of the head.

Fig. 1. Narrowing of lateral recess of left lateral ventricle after pneumography.

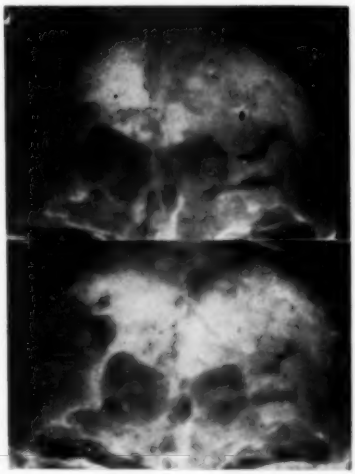

Fig. 2. Widening of subarachnoid spaces on surface of left frontal lobe 1 hour after pneumography.

It is likewise possible to see corresponding changes in the subarachnoid spaces on the brain surface. We have repeatedly found marked dilatation and blurring of the contours of subarachnoid spaces several hours after the insufflation of air, as compared with their size immediately after the procedure. This can also be explained by subsiding oedema of the brain surface (Figs. 2 and 3).

There is yet another way of demonstrating the occurrence of cerebral oedema after pneumography. In a material of 127 cases, 80 ml of a 40 % solution of glucose was injected intravenously immediately after pneumography. Films obtained 5, 10, and 15 minutes after the injection showed immediate dilatation and blurring of contours in 107 patients (84.25 %). In 46 patients the subarachnoid spaces were studied in the same way without the administration of glucose. In 44 cases (95 %) there was no change (Figs. 4 and 5).

Special mention should be made of those cases in which studies both with and without the application of glucose were performed. Reactive dilatation of the subarachnoid spaces was seen only after injection of hypertonic solutions. This led us to the conclusion that a hypertonic solution very probably causes the oedema, resulting from irritation by the air, to subside almost at once. In patients with a history of head trauma the compensatory mechanism which hinders the development of

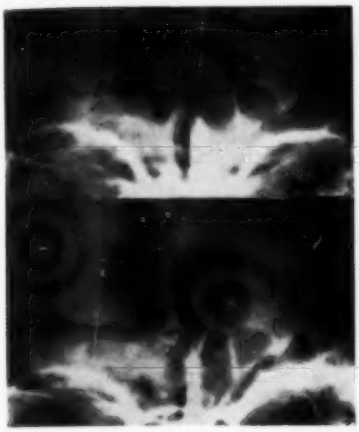

Fig. 3. Widening of subarachnoid spaces on surface of right frontal lobe 4 hrs after insufflation of air.

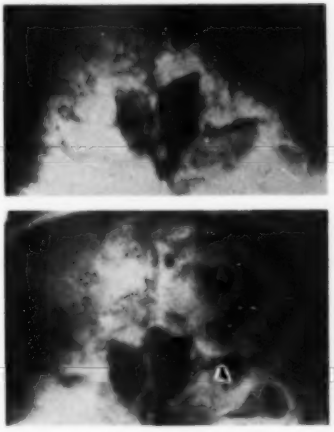

Fig. 4. Widening of subarachnoid spaces on surface of left frontal lobe 10 min. after intravenous injection of hypertonic glucose solution.

oedema is damaged. Brain swelling after pneumography is greater in these cases, and the immediate effect of a hypertonic solution is more marked than in other patients.

The dilatation of subarachnoid spaces could not be observed after the intravenous application of thyroxin. Similarly, the parenteral introduction of a solution of urea, which is known to be a much stronger dehydrating agent than glucose, had less effect on the size of subarachnoid spaces than the latter. Nevertheless, the effect of urea on EEG records was most interesting; in patients with brain tumour and oedema the record became normal immediately after the injection.

We wish to draw attention to variations in the size of the subarachnoid cisterns dependent upon the position of the head. In some patients it is possible by comparing the width of the pontine and intercrural cisterns to discover changes in the relation between the pons and clivus. In anteflexion the pons is displaced forwards towards the clivus. In the supine position it moves backwards, away from the clivus (Fig. 6 b). These movements cannot be seen in cases of posterior fossa tumour (Fig. 7). This sign may be

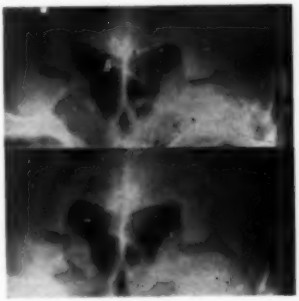

Fig. 5. Marked widening of subarachnoid spaces over left frontal lobe 5 min. after injection of glucose.

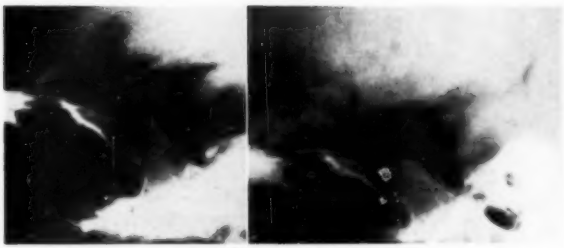

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Fig. 6. a) Narrow pontine cistern in anteflexion of head. b) Widening of pontine cistern in supine position.

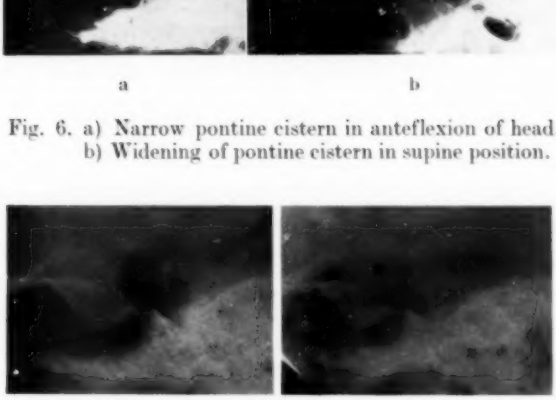

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Fig. 7. a) Narrow pontine cistern in a case of posterior fossa tumour in anteflexion of head. b) Supine. Width of pontine cistern remains unchanged.

utilised in the differential diagnosis between a neoplastic and non-neoplastic lesion in the posterior fossa and is demonstrated by the following case:

Clinical neurologic findings typical of a lesion in the right pontocerebellar angle; there was dilatation of the internal accoustic meatus on the right; the fourth ventricle was slightly displaced to the left and the pontocerebellar cistern elevated and projected medially with its concavity facing the region of the internal meatus. Marked differences in the size of the basal cisterns in different positions of the head did not, however, fit in with the diagnosis of a neoplasm of the posterior fossa. On operation it was found to be a case of arachnoiditis and not a tumour.

Variations of the position of the upper cervical medulla in the spinal part of the cerebellomedullar cistern are a very common finding. In the prone position the medulla is displaced forwards, whereas in the supine position it is moved backwards (Fig. 8). Measurements of the distances between the cervical spinal cord and the anterior or posterior wall of the spinal canal show that herniation of the cerebellar tonsils through the foramen occipitale magnum causes a permanent forward displacement of the cord. Disturbances of the motility of the upper cervical medulla in the spinal canal are important in the diagnosis of spinal tumours, especially those situated in the region of the foramen occipitale magnum where it is sometimes difficult to detect a neoplasm by ordinary films and standard myelography.

The following conclusions may be drawn. Changes in the size and shape of ventricles and subarachnoid spaces and the effect of hypertonic solutions on the brain surface show that contrast media have an irritating effect on brain tissue. The practice of using the least possible amount of

air for pneumography is therefore well founded. This principle has been followed since 1942 in our Neuroradiologic Department.

The extent of changes in the subarachnoid spaces and the possibility of influencing them by hypertonic solutions may be taken as an indication of the intensity of brain disturbances after head injury. Variations in size of the cisterns, which depend on the different positions of the head, may be useful in the diagnosis of brain tumours and in the differential diagnosis between neoplastic and non-neoplastic lesions.

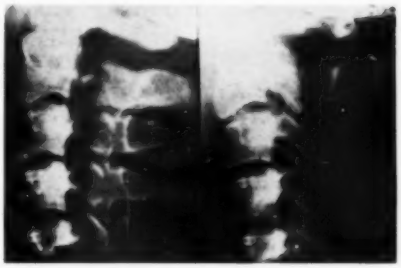

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Fig. 8. a) Supine: distance of anterior surface of medulla from axis is 9 mm. b) Prone: distance between posterior surface of spinal cord and axis is 12 mm (as measured in film).

SUMMARY

Changes in the size and shape of the ventricles and subarachnoid spaces after pneumography are due to the increasing and decreasing of brain oedema, caused in turn by the irritative effect of the air. Attention is drawn to the variations in the size of basal cisterns dependent upon the different positions of the head; these may be helpful in the diagnosis of tumours and in the differential diagnosis between neoplastic and non-neoplastic lesions.

ZUSAMMENFASSUNG

Veränderungen der Grösse und Form der Ventrikel und der subarachnoidalen Räume nach einer Pneumographie sind durch das zunehmende und abnehmende Hirnödem bedingt, welches seinerseits auf der irritierende Einwirkung der Luft beruht. Die Aufmerksamkeit wird auf die Grössenschwankungen der basalen Zysternen, welche auf den verschiedenartigen Kopfstellungen beruhen, gerichtet. Sie können bei der Stellung der Tumordiagnose und der Differentialdiagnose zwischen neoplastischen und nicht neoplastischen Erkrankungen behilflich sein.

RÉSUMÉ

Les modifications de volume et de forme des ventricules et des espaces sous-arachnoïdiens après pneumo-encéphalographie sont dues à l'augmentation et à la diminution de l'oedème cérébral, causé lui-même par l'effet irritant de l'air. L'auteur attire l'attention sur les variations de volume des citernes basales en fonction des différentes positions de la tête; ces variations peuvent aider au diagnostic des tumeurs et au diagnostic différentiel entre lésions néoplasiques et non-néoplasiques.

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AUS DEM RÖNTGENINSTITUT (DIREKTOR: PROF. M. LENZI) DER UNIVERSITÄT MODENA, ITALIEN

ZWEI JAHRE ERFAHRUNGEN UNSERER CISTERNO-ENCEPHALOGRAPHISCHEN TECHNIK

von

M. Lenzi und *G. C. Canossi*

Nach zweijähriger Erfahrung sind wir im Stande über die Vorteile unserer Technik der fraktionierten Cisterno-Encephalographie zu berichten. Diese Technik wurde von LENZI (1953) vorgeschlagen und von LENZI (1954) und CANOSSI (1954) beschrieben.

Unsere Technik besteht darin dass der Patient in Bauchlage auf einem kippbaren Tisch untersucht wird (Abb. 1). Der Tisch ist mit einem kleinen Sattel und zwei Stützen für die Achselhöhlen ausgestattet, um zu verhindern dass der Patient nach unten gleitet wenn der Tisch 50—60 Grad kranial aufgerichtet wird. In dieser Lage steigt die Luft in die endokraniellen Räume auf.

Die Lumbalpunktion wird wie folgt ausgeführt:

a) der Patient wird in Seiten-Bauchlage gebracht, oder

b) der Patient sitzt rittlings auf dem Tisch.

Nach erfolgter Punktion wird der Patient in Bauchlage gebracht und ein Kissen unter den Leib gelegt, um die Lendenlordose auszugleichen. Die Lufteinblasung erfolgt nach den wohlbekannten Regeln der fraktionierten Technik. Man variiert die Kopfhaltung des Patienten derart dass es entweder zur Füllung des Ventrikelsystemes oder/aber der hinteren respektiv vorderen Cisternen kommt. Schliesslich kann man auch alle Liquorräume gleichzeitig füllen, je nachdem wie es die Fragestellung verlangt.

Eine ausführliche Untersuchung der endokraniellen Liquorräume erfordert die drei folgenden Stellungen:

1) Leichte Anteflexionsstellung zur Ausfüllung der Ventrikelräume (Abb. 2a). Damit lassen sich der 4. Ventrikel, der Aquädukt, der Hinter-

Abb. 1. Röntgentisch für die cisterno-encephalographische Technik nach LENZI.

teil des 3. Ventrikels und die Cella media darstellen; Aufnahmen in 2 Ebenen.

2) Der Kopf wird in Flexionsstellung gebracht so dass die Deutsche Horizontale mit der Tischsenkrechten einen abwärts offenen Winkel von 35 Grad bildet (Abb. 2b). Dadurch lassen sich die hinteren cisternen (C. magna, C. cerebellaris superior, C. vena Galeni, C. ambiens) darstellen; Aufnahmen in 2 Ebenen.

3) Dorsalflexion des Kopfes so dass die Deutsche Horizontale mit der Tischsenkrechten einen aufwärts offenen Winkel von 35 Grad bildet (Abb. 3); Darstellung der vorderen Cisternen (C. pontis, C. interpeduncularis, C. chiasmatis, u. s. w.); Seitenaufnahmen.

Nachdem der Tisch wieder horizontal gestellt und die Nadel herausgezogen worden ist, ergänzt man die Untersuchung durch die üblichen Projektionen für die Gehirnventrikel. Wenn es notwendig ist wird man sich auch der Cisternographie in Rückenlage (nach Belloni) bedienen.

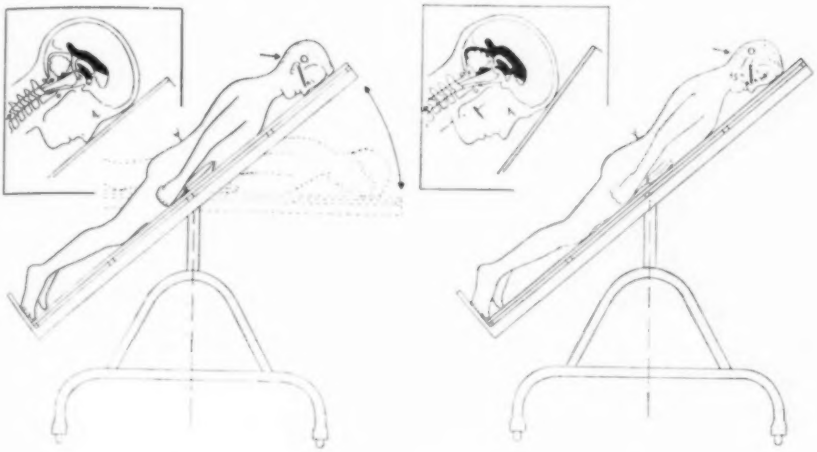

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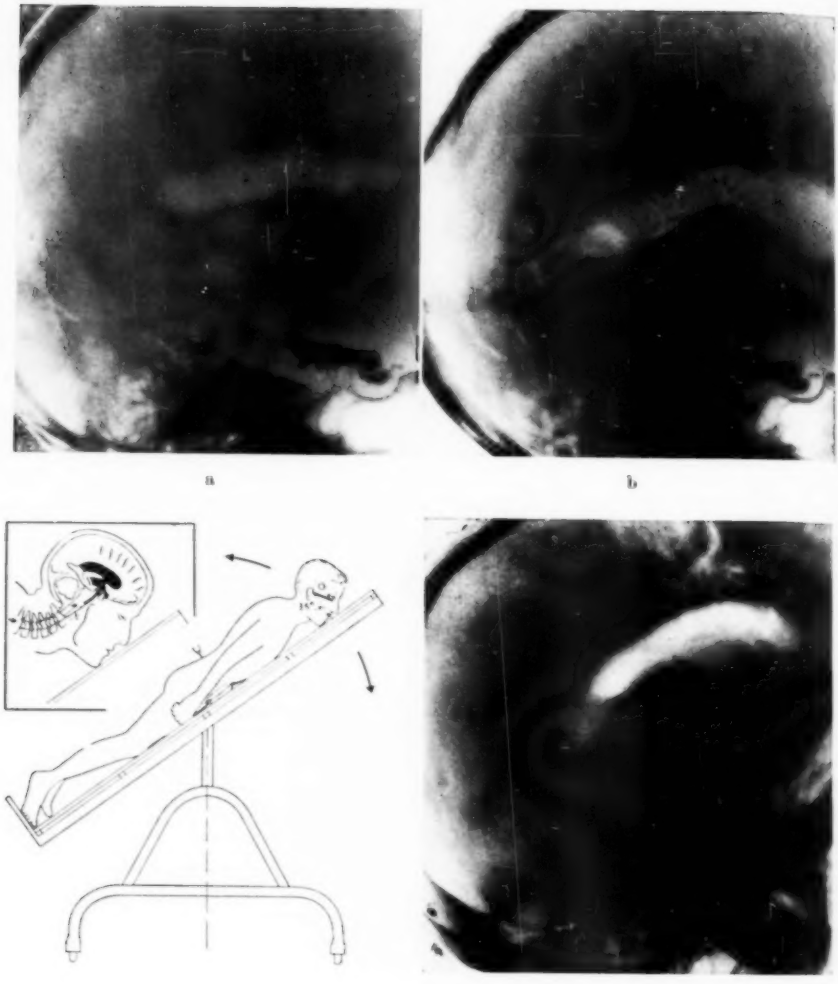
Abb. 2. a) Leichte Anteflexionsstellung zur Ausfüllung der Ventrikelräume.
b) Die Deutsche Horizontale bildet mit einer auf dem Röntgentisch stehenden Senkrechten einen kaudalwärts offenen Winkel von 35 Grad.

Die Vorteile, die wir unserer Technik entnehmen, sind die folgenden. Wenn ein besorgniserregender Zustand eintritt (kann z. B. bei raumbeengenden Prozessen der hinteren Schädelgrube vorkommen), kann der Untersuchungstisch sofort wagerecht gestellt oder in die Trendelenburgsche Lage gebracht werden. Es ist möglich die Untersuchung durch die Cisternographie nach Belloni zu ergänzen und die Ventrikulographie auszuführen ohne den Patienten umzulagern. Es ist möglich Patienten die nicht sitzen können, oder in Narkose liegen, zu untersuchen.

Unterdessen sind in der Literatur Methoden beschrieben worden, die, wenn auch mit einigen Varianten, unsere Methode nachahmen, wodurch freilich die Nützlichkeit und Zweckmässigkeit des Verfahrens endgültig bestätigt wird.



a b c d

Abb. 3. Encephalographie mit Anwendung der gezeigten Flexionsstellungen des Kopfes bei einem Falle von intrakranialen Fremdkörpern. a) und b) Darstellung des 4. Ventrikels, des Aquädukts, des Hinterteils des 3. Ventrikels und der Cella media. c) Die Deutsche Horizontale bildet durch Dorsalflexion des Kopfes mit der Tischsenkrechten einen kranialwärts offenen Winkel von 35 Grad. d) Darstellung der sellären Cisternen.

ZUSAMMENFASSUNG

Es werden die zufriedenstellenden Resultate berichtet, die man nach zweijähriger Erfahrung mit der von LENZI 1953 vorgeschlagenen fraktionierten Encephalographie auf kippbaren Tisch erreicht hat. Durchführungseinzelheiten werden beschrieben.

SUMMARY

The authors describe the satisfactory results obtained over a period of two years in the practical application of fractional encephalography on a tilting table, as proposed by LENZI (1953). Certain aspects of the technique employed in the investigation are dealt with in detail.

RÉSUMÉ

Les auteurs présentent les résultats satisfaisants qu'ils ont obtenus, sur une période de deux ans, dans l'exécution pratique de l'encéphalographie fractionnée sur une table basculante, proposée par LENZI (1953). Ils traitent en détail certains aspects de la technique utilisée dans cet examen.

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DAS PROBLEM DER SUBDURALEN LUFT BEI DER CISTERNO-ENCEPHALOGRAPHIE

von

M. Lenzi, G. C. Canossi, R. Reggiani und *R. Bergonzini*

Bei der Durchführung cisterno-encephalographischer Untersuchungen beobachtet man nicht so selten das Auftreten des gasförmigen Kontrastmittels im endokranialen subduralen Raum.

Die Kenntnis dieser Möglichkeit hat grosse praktische Bedeutung, da die Beurteilung der bei der Cisterno-Encephalographie gewonnenen Bilder bei der Anwesenheit von Luft im subduralen Raum erhebliche Schwierigkeiten bieten kann. Durch Massnahmen, die das Eindringen von Luft in die subduralen Räume verhindern, kann man diese wenigstens in einem gewissen Prozentsatz vermindern.

Häufigkeit und Verteilung. Bei 1,030 Encephalographien, die fast alle mit der lumbalen Methode ausgeführt wurden, haben wir die Anwesenheit von Luft im subduralen Raum in 107 Fällen beobachtet (10.4 %). Von diesen Untersuchungen wurden 644 mit fraktionierter Technik durchgeführt und 386 mit der Methode nach Bingel; subdural gelegene Luft wurde in 14 %, beziehungsweise in 4 % der Fälle beobachtet. Wir glauben, den Unterschied darauf zurückführen zu können, dass bei der Untersuchungstechnik nach Bingel, die wir nunmehr selten anwenden, die Aufnahmen nicht mit erhobenem Kopf und horizontalem Strahlengang durchgeführt werden. Bei dieser Technik wird also die bestmögliche Darstellungsweise von Luft im subduralen Raum nicht benutzt.

Besonders häufig fanden wir subdural gelegene Luft bei Patienten, die an Krankheiten wie Encephalopathie, Arachnoiditis und tuberkulöser Meningitis litten, welche mit Streptomycin auf lumbalem Wege behandelt worden waren, sowie bei Patienten mit Hydrocephalus, cerebraler Atrophie und Komplikationen nach kraniocerebralem Trauma.

Wenn Luft in den endokranialen subduralen Raum eingedrungen ist,

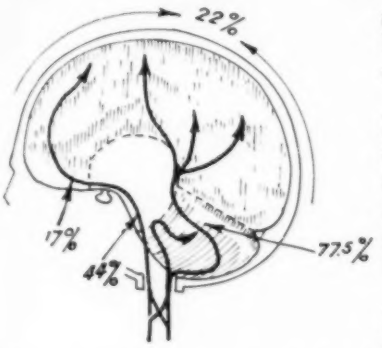

Abb. 1. Verteilungswege der Luft im subduralen endokranialen Raum und Häufigkeit der verschiedenen Lokalisationen.

sammelt sich diese an bestimmten Stellen an, zu denen sie auf den in Abb. 1 eingezeichneten Wegen gelangt.

Statistisch und in abnehmender Reihenfolge beobachteten wir subdurale Luft an folgenden Stellen: a) subtentoriell 77.5 %; b) retrosellär 44 %; c) cortical und interhemisphärisch 22 %; d) Boden der vorderen Schädelgrube 17 %.

In 48.5 % der Fälle mit subdural gelegener Luft fand man diese gleichzeitig und in verschiedener Weise an zwei oder mehreren der obengenannten Stellen. Das Vorkommen von Luft an bestimmten Stellen hängt — je nach der Menge — ausschliesslich von der Kopfstellung des Patienten ab.

Das Eindringen von Luft in den subduralen Raum kann auf dreierlei Weise erklärt werden:

a) Direkte Injektion in den subduralen Raum am Ort des Einstiches;

b) Übertritt vom subarachnoidalen in den subduralen Raum bei Verletzungen der Arachnoidea;

c) Übertritt vom subarachnoidalen in den subduralen Raum auf dem Wege angeborener Lücken. Diese Möglichkeit wird nur von wenigen Autoren angenommen (CAFFEY 1946); nach unserer Ansicht ist sie bisher noch nicht bewiesen worden.

Die Hypothese der direkten Injektion in den subduralen Raum an der Einstichstelle findet die meisten Anhänger. Es handelt sich hierbei um einen technischen Fehler bei der Durchführung der Lumbalpunktion, der auf folgende Weise zustande kommen kann (Abb. 2): 1) nach der Perforierung der Dura liegt die Nadelspitze im subduralen Raum, ohne dass die Arachnoidea verletzt wird; 2) nach der Perforation von Dura und Arachnoidea wird die Nadelspitze teilweise von einem Läppchen der Arachnoidea bedeckt, welches sich wie ein Ventil verhält; 3) nach der Perforierung der Dura und der Arachnoidea liegt die Nadelspitze mit dem äussersten Teil ihrer Öffnung im subarachnoidalen Raum und mit der Basis im subduralen Raum. Im zuerst genannten Fall fliesst kein Liquor aus der Kanüle, in den beiden anderen Fällen fliesst Liquor mehr oder weniger regelmässig ab. Die Luft strömt in den ersten beiden Fällen ausschliesslich in den subduralen Raum ein; im dritten Fall wird sie gleichzeitig in den subduralen und in den subarachnoidalen Raum injiziert.

Wenn Luft in den lumbalen subduralen Raum gelangt ist, steigt sie

im Spinalkanal frei nach oben und gelangt in die endokranial gelegenen subduralen Räume. Man kann die Lage dieser Luftmengen unmittelbar nach der Injektion röntgenologisch feststellen, da die Luft diese Räume mit mindestens der gleichen Geschwindigkeit erreicht, mit welcher die in den spinalen subarachnoidalen Raum injizierte Luft die Cysterne und die Ventrikel zu erreichen pflegt. Die Abb. 3 beweist die Kontinuität der Luftsäule, die sich vom cervicalen subduralen Raum kranialwärts erstreckt. Man sieht den Verlauf dieser Luftsäule durch das Foramen occipitale, längs des Klivus zur Spitze des Sellarückens und zum frontalen Pol, wo diese dann eine grosse Luftblase bildet.

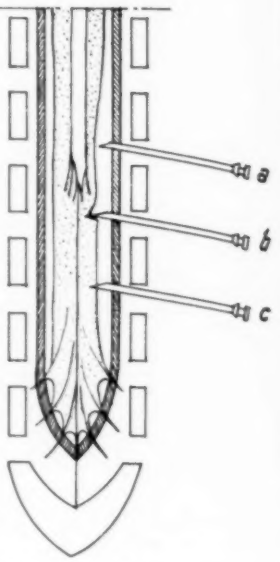

Abb. 2. Lufteindringungsmechanismus in den subduralen Raum während der Lumbalpunktion: a) Nadelspitze im subduralen Raum; b) Nadelspitze teilweise von einem Läppchen der Arachnoidea (Ventilverschluss) bedeckt; c) Nadelspitze teilweise im subarachnoidalen Raum.

Quarti und Fontanari (1952) nehmen an, dass die Liquorentnahme zu einem sogenannten Kollaps der Arachnoidea führt und dass diese sich dadurch von der Dura abhebt. Der subdurale Raum verwandelt sich von einem virtuellen in einen reellen, sodass sich die Kanülenspitze frei in ihm aufhalten kann. Lindgren (1952) hat behauptet, dass man diesen Übelstand durch seine Methode (erste Luftinjektion ohne vorhergehende Liquorentnahme) vermeidet; unsere Erfahrungen stimmen jedoch in vielen Fällen hiermit nicht überein.

Nach unserer Erfahrung ist das direkte Eindringen der Luft an der Stelle des Einstiches am häufigsten. Besonders ist dieses bei Patienten der Fall, die bei der Durchführung der Untersuchung unruhig sind. Bei Anwendung der fraktionierten encephalographischen Methode kann es dann vorkommen, dass die Nadelspitze in den Subduralraum eindringt, wozu schon eine geringe Verlagerung der Nadelspitze genügt. Bei Kindern, bei denen ausserdem der subdurale Raum noch relativ geräumiger ist, tritt dieses Ereignis natürlich häufiger ein. Zugunsten dieses Mechanismus spricht auch die Tatsache, dass es zur Vermeidung des Eindringens von Luft in den subduralen Raum häufig schon genügt, die Lage der Punktionsnadel etwas zu verändern oder die Punktion in einem der angrenzenden Wirbelkörperzwischenräume zu wiederholen. Durch die Lücke, die die vorhergehende Punktion geöffnet hat, dringt jedoch die Luft trotzdem sehr oft in den subduralen Raum ein. Einem geübten Auge kann schon die Art des Liquorabflusses die mehr oder weniger richtige Lage der Nadel anzeigen.

Abb. 3. Kontinuität der cervicalen subduralen Luftsäule mit subduraler endokranialer Ansammlung. Infolge einer früheren korrigierten Einführung liegt auch in den retrosellären Cysternen eine kleine Luftmenge. Am frontalen Pol subduraler Wasser-Luftstand.

Abb. 4. Subdural-retrosellläre »eingesperrte« Luft (charakteristisches Bild in Form eines Delphins) bei Hydrocephalus infolge tuberkulöser Meningitis.

Hinsichtlich der Art des Übertrittes von Luft aus dem subarachnoidalen in den subduralen Raum gibt es Beobachtungen, die das Vorhandensein einer Verletzung der Arachnoidea bestätigen, sei es, dass diese Verletzungen schon vor der Encephalographie bestanden oder dass sie erst während oder nach dieser auftraten. In den beiden ersten Fällen wird man subdural gelegene Luft sofort feststellen können, im dritten Falle kann die Luft erst nach Stunden nachgewiesen werden. Der Kollaps der Arachnoidea (s. oben), die cerebro-meningealen Verwachsungen, die Zartheit des arachnoidalen Gewebes bei Kindern oder ein Hydrocephalus können dem Eindringungsmechanismus einen günstigen Boden bieten.

Röntgenbilder und Differentialdiagnose. Die sicherste Darstellung der subdural gelegenen Luft erhält man auf Röntgenbildern, die bei sitzendem Patienten mit erhobenem Kopf und horizontalem Strahlengang in beiden orthogonalen Ebenen hergestellt werden. Bei liegendem Patienten sammelt sich die Luft an den höchstgelegenen Stellen des Systemes. Abgesehen von der Lage des Patienten ist das Bild der subduralen Luftfalten

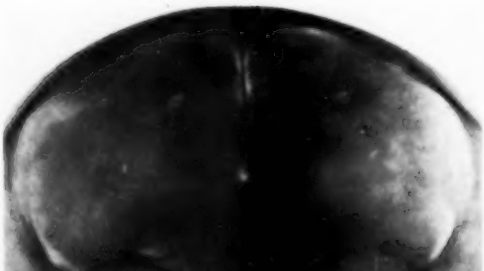

Abb. 5. Subdurale Luft längs der sphenoidalen und interhemisphärischen Kämme.

auch von der eingeblasenen Luftmenge und dem eventuellen Bestehen pathologischer Prozesse (meningeale Verwachsungen, Neubildungen, u. s. w.) abhängig.

Es gibt typische und sofort erkennbare Röntgenbefunde; andere jedoch können bei der Beurteilung erhebliche Zweifel auslösen und somit die Quelle diagnostischer Fehler werden.

Die im subduralen subtentoriellen Raum angesammelte Luft erscheint in der lateralen Projektion (Abb. 6) wie eine Falte verschieden grossen Ausmasses; sie verläuft von der Gegend des Inions schräg nach vorn und aufwärts bis zum Einschnitt des Tentoriums. In vielen Fällen setzt sich diese Falte auch nach hinten abwärts längs des Occipitalenlappens fort, um schliesslich die Oberflächen der Kleinhirnhemisphären abzugrenzen. Bei sagittaler Projektion zeigt das Röntgenbild eine Figur, die etwa mit einem umgekehrten »V« zu vergleichen ist. Dieses Bild muss jedoch deutlich von jenem unterschieden werden, bei dem die Luft in der Cysterna cerebellaris superior gelegen ist.

Die subdurale Luft, die sich in der interhemisphärischen Fissur entlang der Falx sammelt (Abb. 5), erscheint in der sagittalen Projektion wie eine vertikale, zusammenhängende oder unterbrochene Linie. Sie ist in der Mitte gelegen, oft verdoppelt und streckt sich nach oben bis zur Abgrenzung des dreieckigen Teiles des Sinus longitudinalis superior, zusammen mit der Luftfalte der anderen Seite. Je nach der Menge der eingeblasenen Luft kann sich dieses Bild mit Gasblasen verschiedener Grösse seitwärts erstrecken. Die Aufhellungen liegen dann an der Innenseite der Theca und haben einem äusseren gezackten, glatten Rand (entsprechend der Dura parietalis) sowie einem inneren gewellten, glatten Rand. Manchmal kann der innere Rand auf Grund eines subduralen Luft-Wasserspiegels (Abb. 3) geradlinig sein. Die an der äusseren Oberfläche der Hemisphären gelegenen Aufhellungen beobachtet man bei Patienten mit erhobenem Kopf in der Scheitelgegend, bei der Projektion bei liegendem Patienten am frontalen Pol und bei auf dem Bauch liegenden Patienten oder bei erhobenem, aber zum Kinn hin gebeugten Kopf am occipitalen Pol.

An der Schädelbasis versucht die Luft, die Dura von der Arachnoidea

dadurch zu trennen, dass sie längs des Klivus und des Dorsum sellae entlang streicht, ohne die Spitzen des letzteren zu überschreiten. Die durch die Luft verursachte Aufhellung nimmt die charakteristische Form eines italienischen S oder eines Delphins (Abb. 4) an. Diese Form kann leicht von derjenigen unterschieden werden, welche bei der Blockierung der subarachnoidalen Luft gegen die dünne Membrane, die die Cisterna interpeduncularis (LILIEQUIST 1955) von der Cisterna chiasmatis trennt, auftritt.

Abb. 6. Bild cysternaler und subduraler Luft bei retrosellärer Lokalisation. Grosse subdurale subtentorielle Ansammlung.

Gelegentlich und hauptsächlich bei Kindern neigt die Luft dazu, das Hindernis der Processi clinoidei posteriores zu umgehen; sie dringt hierbei längs der Keilbeinkante in die interhemisphärische Fissur oder in die Fissura Sylvii ein (Abb. 5). Häufiger dringt die Luft nach Überwindung der Spitze des Dorsum sellae am Boden der vorderen Schädelgrube entlang bis zur Stirnregion vor.

Der in seiner Deutung schwierigste Befund entsteht durch die gleichzeitige Füllung der perisellären Cysternen und des retrosellären subduralen Raumes. Dabei dringt die subdurale Luft unter die Cysternen und verschiebt diese. Das entsprechende Röntgenbild erinnert fast an einen Schmetterling im Profil (Abb. 6), wobei die Flügel aus der in den Cysternen enthaltenen Luft und der Körper aus der subduralen Luft bestehen.

Zu den »pseudocysternalen« retrosellären Bildern kommen oft noch Luftansammlungen im frontalen subduralen Raum, am Boden der vorderen Schädelgrube sowie auch im subtentoriellen Raum. Die Aufmerksamkeit muss besonders auf die Differentialdiagnose gegenüber normaler Blockierung (siehe oben) oder pathologischer Blockierung der perisellären Cysternen (hauptsächlich interpedunkulär) gerichtet werden.

Das schon beschriebene »delphinartige« Aussehen bietet ein zusammenhängendes, sich nach hinten verengendes und konvexes Aufhellungsbild. Bei einer Blockierung der Cysternen finden wir diese vor dem Hindernis erweitert, nach hinten konkav und in direkter Verbindung mit den hinteren Cysternen oft auch mit einer Erweiterung der Ventrikel verbunden.

Die differentialdiagnostische Beurteilung kann ausserdem dann etwas schwierig sein, wenn die von einer Pontingeschwulst komprimierte Cysterna pontis nach hinten konkav erscheint; andere Aufschlüsse können bei der Untersuchung des IV. Ventrikels und des Aquädukts gefunden werden.

Besonders schwierig ist die Diagnose der cerebralen Athrophie und der Porencephalie, wenn man die Anwesenheit von subduraler Luft vermuten kann. Diagnostische Fehler können auch dadurch bedingt sein, dass eine breite Falte subduraler Luft entsprechend der Konvexität eine Verschiebung und Deformierung des ventrikulären Systems bedingt. Ein weiterer Nachteil der subdural gelegene Luft ist die mangelhafte Füllung des Ventrikelsystems auf Grund der Verschliessung des Foramen Magendie durch die kollabierte Arachnoidea.

Vorteile der Subdurographie. Verschiedene Verfasser lenken die Aufmerksamkeit auf den möglichen diagnostischen Wert der Lufteinblasung in den subduralen Raum (Subdurographie).

Dieses Verfahren kann mit Erfolg bei subduralen Haematomen benutzt werden, womit vor allem der nach der Entleerung bestehende Hohlraum dargestellt werden kann. Auch bei posttraumatischen cerebromeningealen Verwachsungen und Tumoren der Schädeldecke kann die Subdurographie Aufschlüsse über eine mögliche endokraniale Ausdehnung bieten (Lindgren 1941).

ZUSAMMENFASSUNG

Bei 1,030 Encephalographien hat man in 10.4 % der Fälle die Anwesenheit von Luft im subduralen Raum beobachtet. Die Verfasser sind der Ansicht, dass dieses Ereignis auf der Technik bei der Lumbalpunktion beruht. Sie beschreiben u. a. Lokalisationen und Formen der subduralen Luft, die Möglichkeit, die Luft deutlich darzustellen sowie die Differentialdiagnose gegenüber cysternalen Blockierungsbildern.

SUMMARY

The authors have found air in the subdural space in 10.4 % of 1,030 encephalographies performed. As regards the various causes, they consider that the occurrence of subdural air mostly depends on the technique of the lumbar puncture. The situation and appearances of the air, as well as the method of showing it, are described and the differential diagnosis from the signs produced by cisternal block is discussed.

RÉSUMÉ

Sur 1,030 encéphalographies qu'ils ont effectuées, les auteurs ont trouvé de l'air dans l'espace sous-dural dans 10.4 % des cas. Envisageant les diverses causes, ils considèrent que la présence de cet air dépend surtout de la technique de la ponction lombaire. Ils décrivent le siège et les aspects de cet air, ainsi que les méthodes pour le mettre en évidence et discutent son diagnostic différentiel avec les signes dûs au blocage cisternal.

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DIAGNOSTIC VALUE OF ENCEPHALOGRAPHIC EXAMINATION OF THE SUBARACHNOID SPACE

by

Giovanni Ruggiero

At the last Symposium Prof. LINDGREN stated, in summarizing the discussion on encephalography, that at least one thing seemed to be clear: that final words on encephalography had not then been uttered and that there was need for considerably more work on the subject. Since then, the author has in other papers pointed out the value of encephalography either from a purely diagnostic aspect or from the viewpoint of our surgical team. One of the main objections against the use of encephalography, in cases of brain tumour, has been that quite frequently only poor visualization of the ventricular system is obtained, in which case the patient has been subjected to an unnecessary risk. We believe that encephalography can be useful even in cases of unsatisfactory filling of the ventricles, and we hope to demonstrate this in the present contribution.

Table 1

Filling of ventricular system in 680 fractional encephalographies

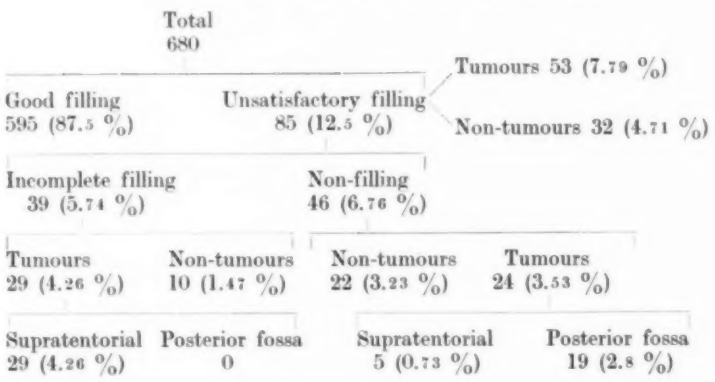


Table 2

Intracranial expansive processes

Total
197

Good filling	Unsatisfactory filling	
144 (73.10 %)	53 (26.9 %)	
	Incomplete filling	Non-filling
	29 (14.72 %)	24 (12.18 %)

The material consists of 85 cases — 53 of which were of tumours — with unsatisfactory filling of the ventricular system, out of a series of 680 encephalographies (Table 1). The total number of tumours in the whole series was 197 (Table 2). All the examinations were performed in our Roentgen Department. The technique was the one described mainly by ROBERTSON and LINDGREN, which we have learned in the Roentgen Department of Serafimerlasarettet, Stockholm.

The term 'unsatisfactory filling' is somewhat vague. There are, as a matter of fact, two possibilities: 'non-filling' and 'incomplete filling'. But since these two groups have some characteristics in common we prefer to use the term 'cases with unsatisfactory filling' to mean both.

Unsatisfactory filling of the ventricular system can be due to technical errors, anatomic variations, and to tumour or non-tumour diseases of the nervous system. We shall here confine ourselves to a brief discussion of cases of tumours; in a work now in preparation, all our cases in the groups of non-filling and incomplete filling will be discussed more in detail. Thus, in the present paper we shall limit ourselves to emphasizing only some aspects of the most common as well as the most difficult cases. First, however, we shall attempt a short statistical analysis of the material.

Table 3

Intracranial expansive processes, non-filling of ventricular system

Localisation	Number of cases	Verified		Not verified
		Anatomically (operation and/or autopsy)	Radiologically	
Posterior fossa	19	17	0	2
Supratentorial	5	4	1 (Arteriography)	0
	24	21	1	2

Table 4

Non-filling of ventricular system in 22 verified cases of intracranial expansive processes

Posterior fossa: 17	Anterior part of posterior fossa: 4		Acoustic neurinoma	2
			Meningioma of post. surf. of petrous bone	1
			Pontine glioma	1
	Doubtful: 1		Neurinoma (possibly acoustic)	1
	Posterior part of post. fossa: 12	Intracerebellar 10	Glioma	6
			Metastases	2
			Angioreticuloma	1
			Tuberculoma	1
		Extracerebellar 2	Meningioma of cerebellar convexity	2
Supratentorial: 5	Extracerebral: 4		Subfrontal meningioma	1
			Parietal meningioma	1
			Fronto-parietal meningioma	1
			Subdural hematoma	1
	Intracerebral: 1		Metastasis	1

Table 5

Incomplete filling of ventricular system in cases of intracranial expansive processes

Site	Cases	Verified				Not verified
		Anatomically (Operation and or autopsy)	Radiologically			
			Carotid Arteriography	Vertebral Arteriography	Ventriculography	
Brain stem	2	1				1
Pineal region	4	3			1	
Thalamic	1			1		
Central	7	4		1	2	
Hemispheres	14	11	1		1	1
Suprasellar	1					1
	29	19	1	2	4	3

The proportion of cases with incomplete filling and with non-filling is almost the same in the whole series. Tumours predominate in the cases with incomplete filling, while in the cases with non-filling they are in almost the same proportion as the non-tumour cases. Moreover, no tumour of the posterior fossa was present in the group of incomplete filling, while these tumours prevail in cases with non-filling (cf. Table 1).

Table 6

Type of incomplete filling of ventricular system and site of lesion in 26 verified cases of intracranial expansive processes

Site	Cases	Type of incomplete filling		
		Almost non-filling	Only infratentorial portion	Only one lateral ventricle
Brain stem	1	0	1	0
Pineal region	4*	0	4	0
Thalamic	1	0	1	0
Central.....	7	0	5	2
Hemispheres.....	13	3	2	8*
	26	3	13	10

* In one case very poor filling, almost non-filling.

Only verified cases have been taken into consideration for the discussion, but we considered as 'verified' not only the cases with anatomic verification at operation or autopsy, but also those in which the presence of a tumour was demonstrated positively by another radiologic examination — either typical deformation of the ventricles on ventriculography, or visualisation of the tumour by arteriorography (Tables 3 and 5).

Tables 3 and 4 summarize the material in the group of non-filling. The majority of cases was represented by tumours of the posterior part of the posterior fossa, which were all verified at operation or autopsy.

Fig. 1. Compression of pontine cistern in a case of diffuse medulloblastoma of cerebellum.

Fig. 2. Herniation of the cerebellar tonsils in a case of neurinoma of posterior fossa.

Tables 5 and 6 summarize the material in the groups of incomplete filling. There were 29 verified cases, of which only 19 were verified anatomically. Table 6 shows the relationship between the site of the lesion and the type of incomplete filling. Tumours of the hemispheres prevail in cases with filling of only one lateral ventricle, while tumours involving the central and mid-line structures represent the majority of cases in which we obtained filling only of the infratentorial part of the ventricular system. Cases with very poor filling or almost non-filling are rare; we have, however, decided to place them in a separate group because even a very small quantity of contrast medium in the ventricles may be of great diagnostic value.

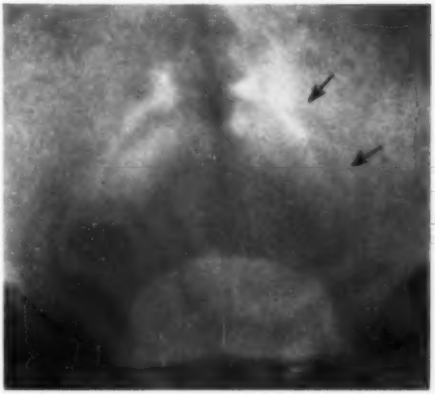
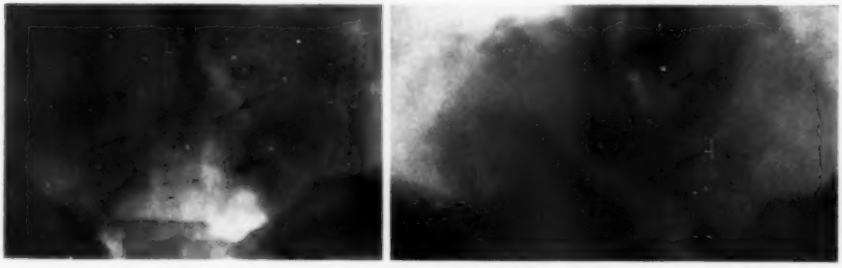


Fig. 3. Left ambient cistern displaced towards midline in a case of metastases in left cerebellar hemisphere.

The diagnosis of a cerebellar tumour, in the absence of ventricular filling, is based on 3 main signs:

1. Flattening of the pontine cistern (Fig. 1);
2. Signs of herniation of the cerebellar tonsils (Fig. 2);
3. Signs of hydrocephalus.

Other signs connected with the cisterns of the posterior fossa and the brain stem (Fig. 3) may be present fairly frequently, but their diagnostic value is not definite, and they will not be dealt with in detail.



a b

Fig. 4. Bilateral acoustic neurinoma. a) At encephalography: two soft tissue masses in cerebello-pontine angles outlined by thin bands of air. b) Ventriculography. Displacement of aqueduct and fourth ventricle. Only the tumour on the right side could be localized with ventriculography.

a b

Fig. 5. Right intraventricular meningioma with temporal herniation. Encephalography. Fourth ventricle on midline, displaced downwards and slightly backwards. Aqueduct not patent. Interpeduncular cistern not visible. Poor visualization of upper part of right ambient cistern which is displaced to the left (a ↘). (The cistern of corpus callosum was displaced. Ventriculography showed a large tumour in the right lateral ventricle; encephalography localized the tumour but did not indicate its nature.)

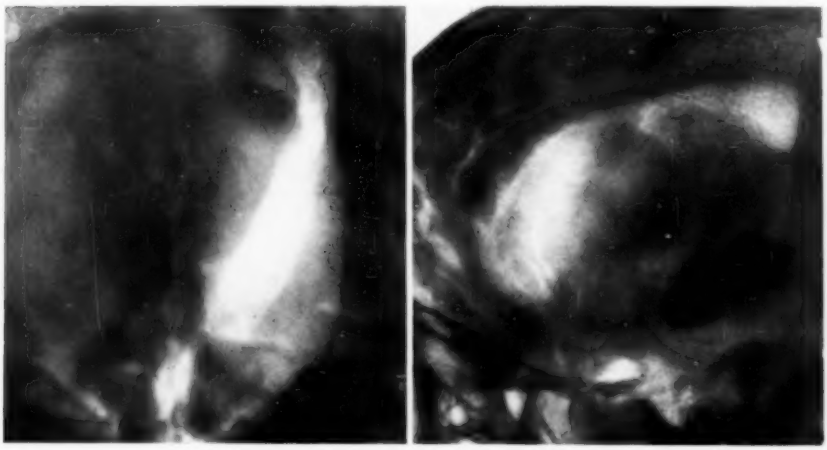
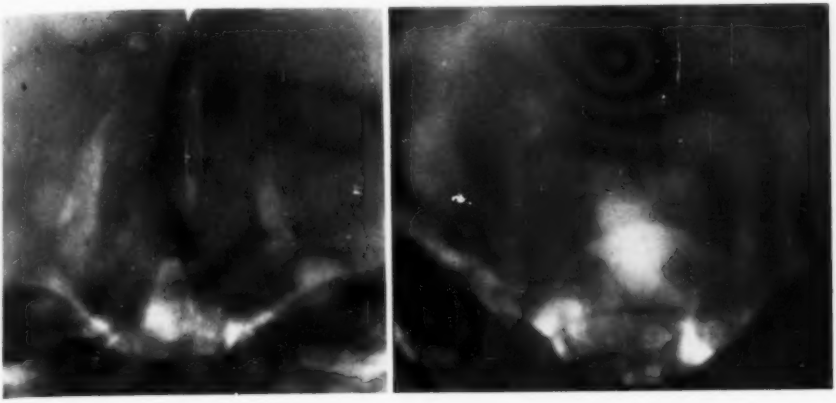


Fig. 6. Neurospongioma of septum pellucidum and corpus callosum. Encephalography indicated site of lesion and its intracerebral situation, which was confirmed by arteriography.



a b

Fig. 7. Different aspects of cisterns of brain stem in a case of tumour involving midline and paramedian structures.

a) Pinealoma. No visualization of cisterna venae magnae Galeni or upper part of left ambient cistern.

b) Large tumour of left thalamus displacing and invading brain stem. Right ambient cistern displaced to the right; only lowest part of left ambient cistern visible (↙). No visualization of cisterna venae magnae Galeni.

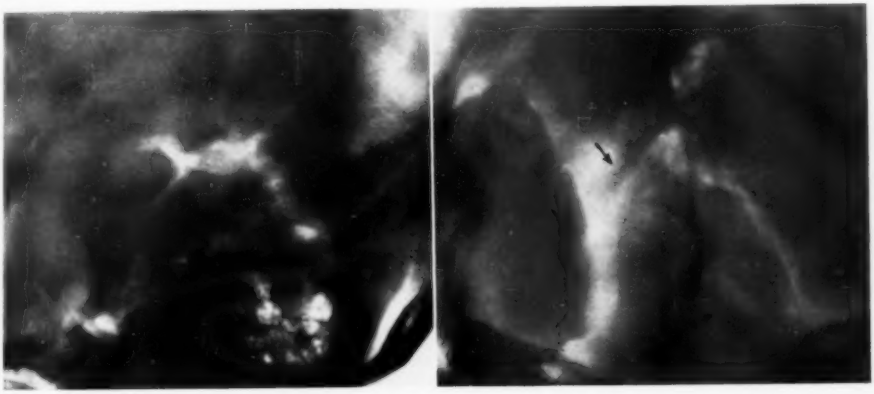


Fig. 8. Tumour in right cerebral peduncle. Ambient cisterns are narrow and the right displaced upwards and to the right. Cisterna venae magnae Galeni flattened and displaced to the right. Fourth ventricle displaced to the left (↘).

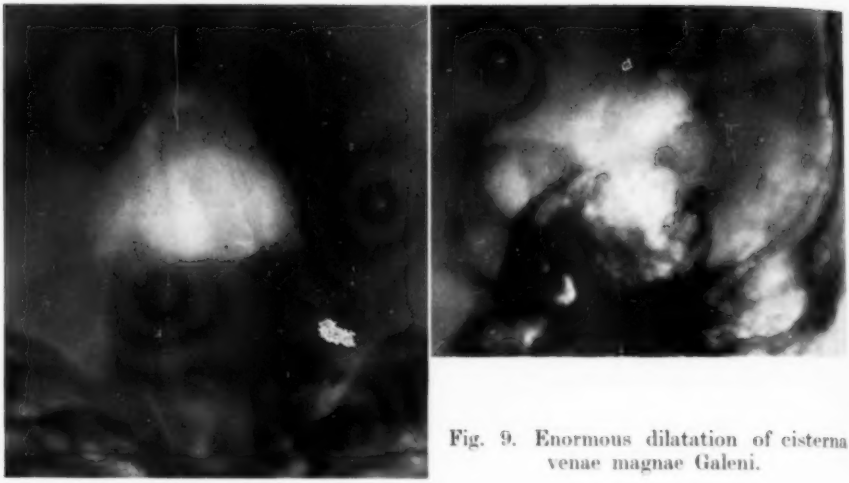


Fig. 9. Enormous dilatation of cisterna venae magnae Galeni.

In cerebellopontine angle tumours, satisfactory filling of the ventricular system may usually be obtained but in some cases this is not so; encephalography may give excellent results (Fig. 4). In supratentorial tumours it is impossible to present the findings schematically, since each case differs from the other; this is demonstrated by the examples in Fig. 5.

In cases with filling of only one lateral ventricle, three signs are important:

1. The relationship between the septum pellucidum and the third ventricle;
2. The appearance of the subarachnoid space;
3. The contours of the filled ventricle.

Regarding the relations between the septum pellucidum and the third ventricle, the problem to be solved is evidently the same as encountered in cases in which the two lateral ventricles are filled. Non-filling, or poor filling of the subarachnoid spaces on the convexity of the brain is indicative but not diagnostic. Their deformation — especially of the sylvian fissure — is much more useful.

The study of the contours of the filled ventricle and of the third ventricle is extremely important, since it represents the only means of establishing whether non-filling of the lateral ventricle is due to direct compression (Fig. 6) rather than to indirect compression (through oedema) caused by a tumour situated outside the ventricle. In one of our cases — a right fronto-parietal tuberculoma — autopsy revealed

that the homolateral ventricle was completely collapsed but not in contact with the tumour which was situated laterally to the internal capsule.

In tumours of the brain stem, and in supratentorial tumours involving the structures of the midline, or in tumours growing into the central grey matter, in which only the infratentorial portion of the ventricular system is filled, the diagnosis is difficult. It is confined chiefly to the study of the cisterns of the brain stem. As far as tumours of the brain stem are concerned, the first problem to be solved is that of the differential diagnosis from non-tumourous stenosis of the aqueduct.

We have studied the encephalographic appearances of this latter condition in another paper (RUGGIERO). Our conclusion was that the diagnosis is based on the dilatation of the cisterns of the brain stem — especially the cisterna venae magnae Galeni — which is sometimes considerable. This sign, however, is only valid for a differential diagnosis between tumours of the brain stem and non-tumourous stenoses of the aqueduct, since atrophy of the brain stem accompanied by dilatation of the cisterns may also be observed in cases of hydrocephalus caused by tumours situated elsewhere than in the brain stem. Figs. 7—9 show some examples of the more typical changes.

Large diffuse bilateral tumours represent the most difficult problem of all cases with unsatisfactory filling of the ventricular system. The only valuable sign seems to be non-filling or deformation of the cisterna corpori callosi. Ventriculography is usually necessary for diagnosis, but arteriography may also be very useful.

SUMMARY

The author has studied 53 cases of cerebral tumour in which fractional encephalography was carried out and in which unsatisfactory filling (either non-filling, or incomplete filling) of the ventricular system was obtained.

ZUSAMMENFASSUNG

Der Verfasser hat 53 Fälle mit Hirntumoren untersucht, bei denen die fraktionierte Enzephalographie durchgeführt wurde und bei denen man keine oder eine nur unzureichende Füllung des Ventrikelsystemes erhielt.

RÉSUMÉ

L'auteur a étudié 53 cas de tumeur cérébrale chez lesquels une encéphalographie fractionnée a été effectuée et où on n'a pu obtenir qu'un remplissage non-satisfaisant (nul ou incomplet) du système ventriculaire.

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DISCUSSION OF ENCEPHALOGRAPHY

M. David (Paris):

It is a great honour for a neurosurgeon to be asked to address so many eminent neuroradiologists here today — but it also means a duty. It is absolutely essential to establish more and more close and frequent contacts between our two specialities for the greatest benefit of our patients and development of our knowledge. I am taking advantage of the opportunity offered to me by the communication of G. RUGGIERO to point out once more the position of the neurosurgical team of the Ste Anne Hospital of Paris with regard to fractional encephalography by the lumbar route, particularly in connection with its use for the diagnosis of cerebral tumours. And this all the more so since none of you are insensible of the opposition encountered in such cases on the part of neurosurgeons in all countries.

It is not without a certain apprehension that, having been brought up in the doctrine of the absolute contra-indication of lumbar puncture in the syndromes of intracranial hypertension, broken by the practice of ventriculography for the past 25 years, I decided to experiment with fractionated encephalography in cases in which intracranial tumours were suspected.

In the beginning we intended to reserve this method for cases in which ventriculography and arteriography proved valueless in providing a precise diagnosis, namely for certain tumours of the middle and posterior fossa, a number of tumours of the base, and neoplasms of the brain stem. We soon found out that the method permitted results of far higher precision than classic ventriculography, and at the same time caused less injury, and that it was expedient to extend its indications. We decided to apply fractionated encephalography in place of ventriculography as a routine measure, at least for the first examation.

At present our experience permits us to affirm that with fractionated encephalography we have at our disposal a very precise method which appears to be superior to classic ventriculography, although in some cases

there may be indications for completing the findings obtained by the injection of air by the ventricular route.

However, introducing air by 'lumbar puncture' to a patient suffering from a cerebral tumour still seems to many neurosurgeons to be an act of sacrilege. In reality this conviction is based on an ambiguity. One must beware, indeed, of comparing the classic encephalography by lumbar puncture, evacuation of a large quantity of fluid and injection of 80 to 120 ml of air, with fractionated encephalography in which the fluid-air-exchange is regulated according to the condition of the patient and the lesion towards which the neuroradiologist is oriented by the statements made at the beginning of the examination. As paradoxical as it may sound, the danger of herniation seems less to us with this technique, in which the air performs its action from below upwards, and in which the subtraction of fluid is late and very small, than with ventriculography in which the fluid pressure is directed from above downwards. It is a fact that during the past three years, in which fractionated encephalography has been performed regularly by G. RUGGIERO in patients suffering from cerebral tumours, accidents have been exceptional.

Ventriculography itself is, incidentally, not free from inconveniences or even danger. It makes puncture of the brain substance necessary, sometimes causing a haemorrhage or at least bleeding in the canal of puncture in the occipital lobes or the thalamus. Transitory hemianopsia is not rare and temporary cortical blindness not exceptional. But above all, the considerable quantity of air, which must be injected into the ventricles of a brain long compressed in order to obtain sufficient contrast density, may rapidly cause the onset of cerebral oedema, a danger which, though not always bringing about convulsions or coma, complicates the task of the surgeon and aggravates the operative prognosis. On the other hand, we were favourably impressed by the absence, or the minor importance of oedematous reactions in patients who had undergone fractionated encephalography by the lumbar route, even when the surgical intervention took place several days after the injection of air.

Immediate surgical intervention required by classic ventriculography is generally not obligatory in cases of hemispheric tumours, except in those with considerable intracranial hypertension, or in which the general condition is poor. We may add that fractionated encephalography is in general much better borne than angiography by aged subjects and by patients suffering from arterial hypertension.

In cases of tumours of the posterior fossa one must be more cautious and ready to intervene during the hours immediately following the roentgen exploration, especially when fractionated encephalography has shown herniation of the cerebellar tonsils, sometimes clinically dumb.

Conclusions. The chief advantages of fractionated encephalography seem to be:

a) a greater precision in diagnosis;

b) less possibility of injury accompanying it, and, consequently, the ease with which it is borne by the patient;

c) the increased frequency of early diagnosis which it permits, a fact evidently resulting from a) and b);

d) the interest of this method in non-tumourous brain pathology and its contribution to stereotaxic techniques.

It is well understood that all I have said assumes that fractionated encephalography is carried out with rigorous control of the technique and according to the particular and authoritative rules of the Swedish school led by Prof. LINDGREN and his disciples.

The era of the neurosurgical radiologist thus seems to have faded. No doubt, some useful function on his part may still be conceived in small centres, or on special occasions, especially when emergencies arise; but when more and more precise and particularly early diagnosis is required, and especially where progress is the concern, it is essential that a neuroradiologic team be constituted, possessing sufficient autonomy as far as neurosurgeons as well as neurologists are concerned. All this provided that intimate and constant, and, if necessary, immediate contacts can be established between the two specialities: neuroradiology and neurosurgery. The problem of contacts between the neuroradiologist and the neurosurgeon has been discussed in detail in: *Report of the Congress of Neurosurgery*, Algiers, April 1954 (in French. Revue Neurologique, 90 (1954), 434, 591.) The neuroradiologist will then be responsible for the diagnosis. The neurosurgeon will decide in collaboration with the neuroradiologist the method of radiographic investigation to be carried out, but will hold entire final responsibility for the indications for operation.

FROM THE DEPARTMENTS OF RADIOLOGY, ST. BARTHOLOMEW'S HOSPITAL AND THE NATIONAL HOSPITAL FOR NERVOUS DISEASES, MAIDA VALE, LONDON, ENGLAND

THE SIGNIFICANCE OF DIGITAL IMPRESSIONS IN CHILDREN'S SKULLS

by

George du Boulay

The purpose of this study has been to determine whether the gyral impressions on the inner table of the vault are altered by a rise in intracranial pressure. The roentgenographic representations of these thinned areas of the skull have been given the name of digital impressions. The pattern produced is also known as silver beating, copper beating, hammer marking, convolutional atrophy, and convolutional markings.

Conclusions in this paper are drawn as a result of comparison between the skulls of abnormal and normal children and from the clinical evidence in a series of abnormal children. Additional data were provided by the repeated roentgenologic examination of some children of this series during their illness and following their recovery.

Many authors have stressed the difficulty of distinguishing between normal and abnormal degrees of convolutional markings, but most are of the opinion that deep and numerous markings are associated with raised intracranial pressure.

However, the two detailed analyses of the digital impressions in childhood are concerned almost exclusively with the normal. DAVIDOFF (1936) examined a large number of roentgenograms of the skulls of normal children and assessed the depth and extent of the impressions in the frontal, parietal, occipital, and temporal areas, separately, according to an arbitrary scale reading from 0 to 6. He published the results in the form of graphs which showed the convolutional markings determined in his experimental units, from the ages of six months to 18 years. He gave separate curves for each area of the skull, a fifth curve representing the average of all areas. MACAULAY (1951) published the second normal series. His method of assessment differed slightly from that

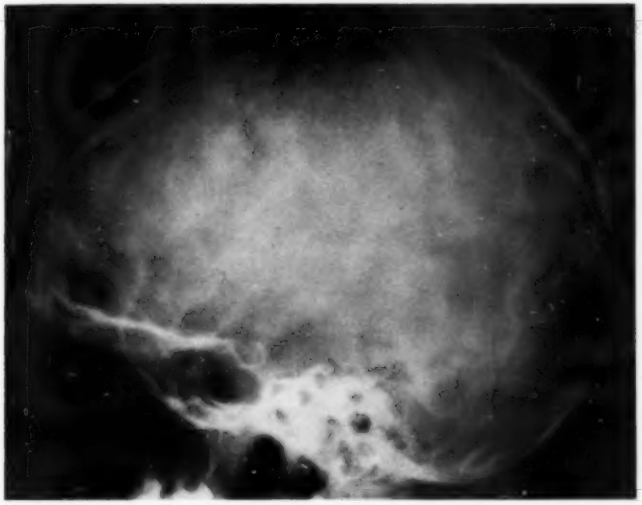

Fig. 1. Normal skull. Heavy digital impressions rated: frontal 3, parietal 3, and occipital 3.

of DAVIDOFF in that he used only three grades of extent and depth of digital impressions. '1' represented just descernible markings, '3' were markings of the most prominent kind and '2' lay intermediately between '1' and '3'. From the average of the children in each yearly age group, from one to fourteen, he produced a curve in the same way as DAVIDOFF. He also published useful figures showing the amount of variation within each age group. As DYKE (1941) had previously stated, MACAULAY noted that the digital impressions in the skulls of children with hypoplastic brains are significantly less than in normal children. It is difficult to compare MACAULAY's and DAVIDOFF's figures. Their empirical units are entirely subjective; and it is not certain that MACAULAY's 0—3 runs in step with Davidoff's 0—6. If one assumes that there is a simple relationship of this kind between the units, then it would be necessary to divide DAVIDOFF's figures by 2 in order to produce a curve on the same scale as MACAULAY's. When such a pair of curves is shown, DAVIDOFF's is lower than MACAULAY's, suggesting that the children in his series had fewer, and shallower, convolutional markings (Diagram 1).

However, both series show few or no convolutional markings before the age of one year. Thereafter, there is a swift and steady rise to about the fourth birthday, then a plateau until the age of nine or ten followed by a steady decline for four years, and a slight rise after the 14th birthday.

Fig. 2. Normal skull. Slight digital impressions rated: frontal 1, parietal 1, and occipital 2.

Material. The material consists of the roentgenograms of 159 children from the Neurosurgical units of St. George's and St. Bartholomew's Hospitals, London, up to 1952. All the children were reported on clinical grounds as having undoubted evidence of raised intracranial pressure; the roentgenograms were of good quality. Many of the cases had progress notes extending over months or years. When a roentgen examination coincided with a full note on the child's condition, it was possible to add to a 'follow-up' series. The skull roentgenograms of 199 normal children over the same age range were also collected. None of these had any history to suggest a rise in intracranial pressure.

Technique. The technique was derived from MACAULAY (1951). The frontal, parietal, occipital, and temporal areas were examined in turn. Marks were awarded to each area according to the following scheme:

a) No impressions visible 0
b) Few and shallow impressions 1
c) Deep and extensive impressions 3
d) Impressions intermediate between (b) and (c) 2

(See Figs. 1 and 2.)

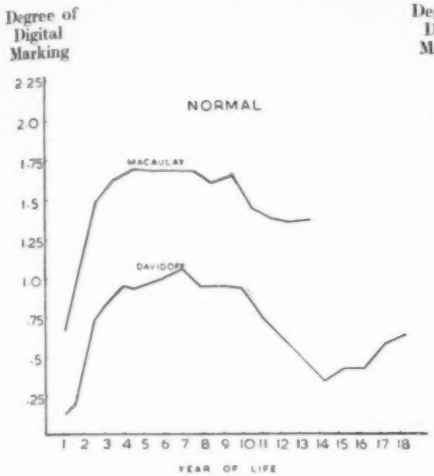

Diagram 1. Alteration of digital impressions with age.

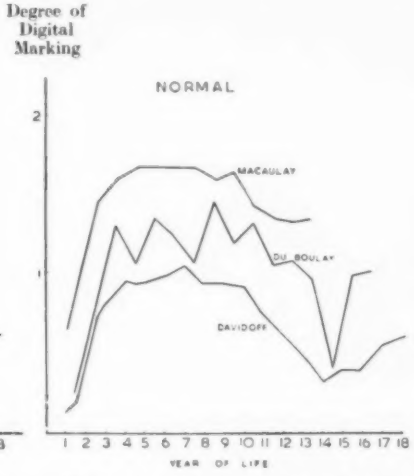

Diagram 2. Present series of roentgenograms of skulls of normal children assessed in the same way as MACAULAY'S. The two curves show the same general configuration.

The total marks awarded to each skull was divided by the number of areas examined, *i. e.* 4. The result was an index for that particular skull. An average of the indices obtained for each skull in each age group permits a graph to be drawn. Comparison of curves obtained in this way from different groups of children provides the basis of this paper.

The criteria upon which the intracranial pressure was judged were: 1) a history of headache and vomiting, 2) the presence of papilloedema, 3) the measurement of the C. S. F. pressure at ventriculography or lumbar puncture, 4) the presence of suture diastasis and 5) changes in the sella turcica in the absence of a local disease process such as a craniopharyngioma. Most of the direct pressure measurements must have been made either with the child crying, or anaesthetised; and not too much weight can be attached to them.

All the particulars, except observations upon roentgenograms were obtained from the notes. The criteria were strictly applied, and though not all the manifestations of raised intracranial pressure were present in every case, no reasonable doubt remained that the pressure had been substantially raised within two or three days of the roentgen examination.

Observations

First examination. The curve obtained from the normal series in the manner described, exhibits the same general characteristics as the ones

Diagram 3. Comparison between the present normal and abnormal series at different ages. On the whole the abnormal rates higher than the normal.

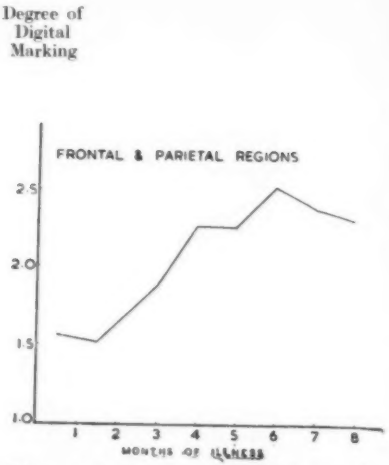

Diagram 4. Degree of digital impressions in frontal and parietal regions of children of 3 to 9 years plotted against length of illness. The units represent an average of the sum of the markings in the two areas of all children in each 'length of illness' group.

published by DAVIDOFF and by MACAULAY but lies intermediate in position between the two (Diagram 2). A sharp rise to the third year is followed by a plateau until the tenth year, after which there is a steady fall. If this normal curve is compared with one representing the whole abnormal series, it is seen that generally the abnormal rates higher than the normal (Diagram 3). At three points, however, the relationship is reversed.

The total abnormal series, however, contains children with histories of very short, as well as very long duration. It is presumed that some weeks are required to produce macroscopic cranial bone changes; and analysis of the figures suggests that, for children of 3 to 9 years, between two and three months are required to cause alteration in the digital impressions visible in the roentgenograms (Diagram 4).

The abnormal series has, therefore, been divided into two groups:

1) those with histories of ten weeks or less;

2) those with histories suggesting raised intracranial pressure of longer than 10 weeks duration.

These two groups are compared in Diagram 5. Where sufficient children for satisfactory comparison remain in each group, the longer history always rates higher than the shorter. If only the frontal and

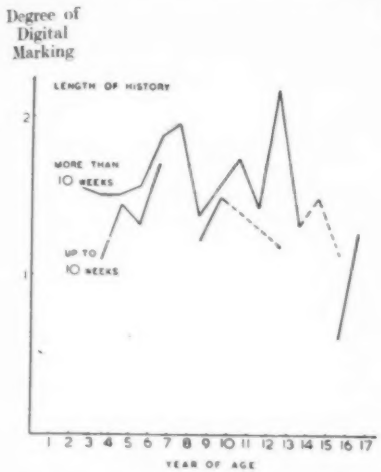

Diagram 5. Abnormal series divided into two according to length of history. The digital impressions of those with longer history are more marked. Broken lines represent age groups in which there are few children. Where no line is drawn the numbers of children in the age groups are below 3.

Diagram 6. Children with suture diastasis have been picked out and contrasted with whole abnormal group (they are therefore also represented in lower curve along with those without this sign of raised intracranial pressure).

parietal regions are compared, the difference between the normal and abnormal cases is still more striking.

The length of history, however, especially when obtained from the notes, is not a very accurate way of determining the duration of a rise in intracranial tension. Suture diastasis is an additional radiologic sign in most children over the age of three years that the pressure has been raised for at least a month. If the children with suture diastasis are singled out, a curve may be obtained in the same way as before. This curve is found to be consistently higher than that from children with short histories, and is also higher than the curve for all the abnormal children. (In three age groups all or nearly all the children had suture diastasis. Here the two curves run together.) (Diagram 6.)

Children with papilloedema or consecutive atrophy exhibit an average of markings rather less than the suture diastasis figures, but more than the 'short history' curve.

There are 5 children in the series with aqueduct stenosis. Presumably the rise in intracranial pressure has been of very long standing. Four (4) have digital impressions of a gross degree.

Progress. Thirty-nine (39) re-examinations were carried out on 34 children. Complete relief of raised intracranial pressure of more than three months' duration was seen on 10 occasions, the youngest child being nearly five years old. At re-examination, eight (8) of these children showed a small decrease in the digital impressions; only 2 had an increase (which was similarly small).

Of the 7 cases surviving for more than three months with persistently raised intracranial pressure, 3 showed an increase in the digital impressions. One (1) was unchanged, and 3 showed impressions of a decreased degree. Two (2) of these latter, children of 15 months and 3 years, respectively, developed extreme suture diastasis and lived for more than four months in one case, and one year in the other. The sella turcica of each became affected by the raised pressure during the period of observation. It may be that in such cases suture diastasis enables the child to survive, whilst the convolutions become so swollen as both to alter their relationship with the overlying vault and to obliterate the intervening sulci. Thus the vault becomes uniformly thinned.

In 22 cases there was doubt about the duration of relief of raised intracranial pressure. Headache and vomiting, for instance, had recurred for a day or two before the second examination. Twelve (12) of these children showed diminished digital impressions, 7 remained unaltered and 3 showed an increase.

Discussion

It is clear that a rise in intracranial pressure which is persistent for longer than ten weeks, begins to influence the moulding of the skull to the brain. The gyral depressions in the vault deepen sufficiently to cause an increase in the depth and extent of the digital impressions as seen roentgenographically. The same general tendency is observed in the progress series, though in very young children the ease with which the skull may be distended can alter the effect. With the relief of pressure and shrinkage of the brain, there may be a tendency for the digital impressions to become filled-in to some degree.

However, to evaluate these markings as a radiologic sign, it is not sufficient to appreciate that they increase during a prolonged rise in intracranial tension. The normal range at any age must also be known.

Unfortunately, the most extensive and heavy impressions may sometimes be found in normal children. If all four regions of the vault are considered, between one tenth and one third of the normal children have ratings higher than the average of the children of the same age with suture diastasis. If only the frontal and parietal regions are compared, fewer, but still a substantial number of normal children exhibit

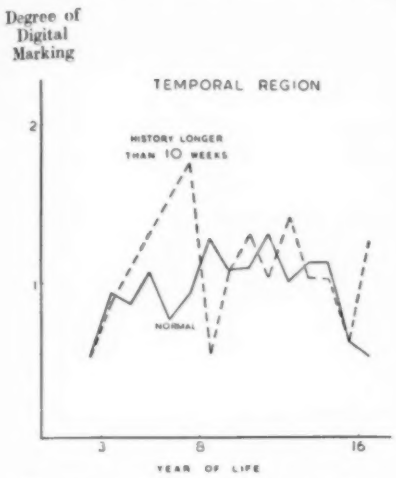

Diagram 7. Digital impressions, in temporal region only, of children with raised intracranial pressure of some chronicity; contrasted with temporal region of normal children at same ages; little alteration between health and disease.

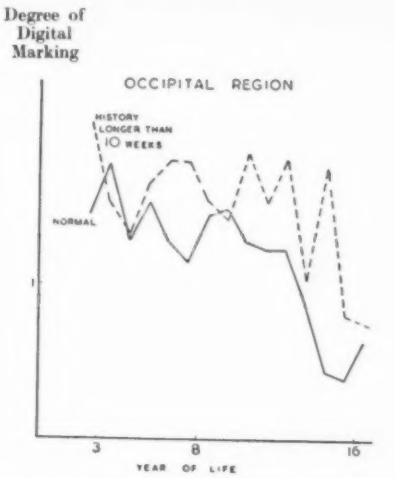

Diagram 8. Occipital (supra-tentorial) region shown in the same way as in diagram 7. The two curves are slightly wider apart.

markings grosser than the general run of those with chronic intracranial high pressure. Moreover, those few children with raised intracranial pressure of more than six weeks' duration, whose skulls showed neither suture diastasis nor changes in the sella turcica, for the most part exhibited digital impressions of only a moderate degree. One is therefore led to the conclusion that although a rise in intracranial tension increases the digital impressions, this is of secondary importance as a radiologic sign of raised intracranial pressure, because: 1) too many normal children have pronounced markings, and 2) suture diastasis or sella changes are likely to take place before the gyral impressions become very deep.

Heavy digital impressions cannot, however, be entirely disregarded. When present, and when there is also other evidence of raised intracranial pressure in children from four to sixteen years of age, the chances are of the order of 2 : 1 in favour of an intracranial process of 10 weeks' or longer duration. This is even more likely if the impressions are particularly marked in the frontal and parietal regions.

Mechanism. Growing bone moulds itself according to the stresses brought to bear upon it and is particularly susceptible to pulsating pressures. Arteries for instance cause depressions where they cross bone,

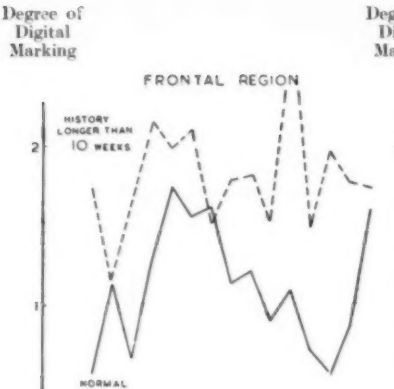

Diagram 9. Frontal region. There is a greater difference between average of digital impressions in normal and abnormal children.

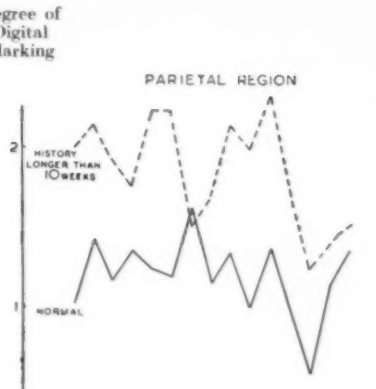

Diagram 10. Parietal region. Difference between curves is much the same as in frontal region.

and aneurysms cause dilatation of these bony channels. The brain is an organ which pulsates, and were it not cushioned by a surrounding layer of fluid, might be expected to mould the inner table of the vault exactly to its own form (the dura being little bar to the transmission of pressure).

The specific gravity of cerebro-spinal fluid is such that the normal brain will sink in it. This sinking will ensure that the layer of fluid varies in thickness over the surface of the brain according to the posture of the head. After infancy the head is carried erect for about twelve in every twenty-four hours, and during most of this time the layer of fluid between gyri of the base of the brain and skull must be extremely thin. Over the upper part of the cerebral cortex, on the other hand, the convolutions are covered with a thicker layer of C. S. F. The thick layer of fluid propagates the pulsating pressure equally to all parts of the inner table of the skull to which it is adjacent.

The microscopic layer of fluid over the gyri of the base allows direct pressure between brain and dura. (An additional factor here may be that in the sulci of the base, movement of the fluid upwards and outwards with the advancing pressure wave permits the application of what elasticity there is in the system. The result is that there is a less sudden rise in the pulse of pressure brought to bear on the bone opposite the

sulcus.) In sleep and recumbancy, only one half of the vault can lie below the brain and the lowest part is usually the occiput. Thus the skull base is probably subjected to the more direct kind of gyral pressure for three times as long as the upper parts of the vault. Though no doubt a simplification, this concept explains the persistence of deep gyral impressions on the orbital plates and on the lateral parts of the floor of the middle fossa, while in adults the vault has fewer and shallower mouldings.

With intracranial expanding lesions, the peripheral layer of C. S. F. generally tends to be diminished. The brain, in expanding, squeezes away the subarachnoid fluid cushion. Gravity ensures that the thickest layer of fluid remains uppermost; but finally even over the top surface of the brain the gyri are only covered by a microscopic fluid layer, and thus the upper parts of the cortex may exercise the same influence on the vault as the under-surfaces do upon the skull base.

These ideas are borne out by the following observations.

If a chart is made of the degree of digital impressions in the temporal regions in healthy children as well as in those who have had high intracranial pressure for more than ten weeks, little difference is seen between the two sets of figures (Diagram 7).

The occipital region examined in the same way shows a rather greater alteration from health to disease (Diagram 8).

The frontal and parietal regions, on the other hand, show a much greater degree of rise in digital impressions with increase in intracranial pressure (Diagrams 9 and 10).

Acknowledgment

I wish to record my indebtedness to Dr. MACAULAY who inspired this contribution and my thanks to Dr. JAMES BULL, Mr. JOHN O'CONNELL, and Mr. MCKISSOCK for their permission to use the material. The graphs were drawn by Mr. ERIC LOVE.

SUMMARY

An attempt has been made to discover what effect a rise in intracranial pressure has on the digital impressions in the skull vault in childhood, and how soon the effect is manifest.

About ten weeks of raised intracranial pressure is necessary before any great increase in the digital impressions takes place. Before this time has elapsed there is nearly always other radiologic evidence of intracranial hypertension. The normal appearance is variable, and a number of children do not exhibit marked digital impressions after prolonged high intracranial pressure. Deep and numerous digital impressions which alone are of no great importance may, in the presence of other signs, point towards a long-standing condition.

ZUSAMMENFASSUNG

Ein Versuch wurde gemacht festzustellen, welchen Effekt ein Ansteigen des intrakraniellen Druckes auf die impressiones gyrorum des kindlichen Schädeldaches hat und wie schnell dieser Effekt manifestiert wird.

Die intrakranielle Drucksteigerung muss etwa 10 Wochen lang vorhanden sein, bevor eine deutliche Zunahme der impressiones gyrorum stattfindet. Vor Ablauf dieser Zeit findet man beinahe immer andere röntgenologische Merkmale eines gesteigerten intrakraniellen Druckes. Das normale Aussehen ist variabel; eine Reihe von Kindern zeigen auch nach langdauerndem hohen intrakraniellen Druck keine deutlichen impressiones. Tiefe und zahlreiche impressiones gyrorum, welche allein nicht von grossem Interesse sind, können zusammen mit anderen Merkmalen auf einen seit langerer Zeit bestehenden Zustand hinweisen.

RÉSUMÉ

L'auteur s'est efforcé de déterminer dans quelle mesure une élévation de la pression intracranienne influe sur les impressions digitiformes de la voûte du crâne chez l'enfant et au bout de combien de temps son effet est manifeste.

Il faut environ dix semaines d'hypertension cranienne avant que se produise une augmentation importante des impressions digitiformes. Avant l'écoulement de ce délai il apparaît presque toujours d'autres signes radiologiques d'hypertension cranienne. L'aspect normal est variable et un certain nombre d'enfants ne présente pas d'impressions digitiformes marquées après une hypertension cranienne prolongée. Les impressions digitiformes profondes et nombreuses qui, isolées, ont peu d'importance, peuvent, en présence d'autres signes, indiquer une affection de longue durée.

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AUS DEM UNIVERSITÄTS-NERVENKLINIK (DIREKTOR: PROF. DR. H. KRANZ), MAINZ, DEUTSCHLAND

ZUR ABLEITUNG VON ENTWICKLUNGSVORGÄNGEN AUS DEM RÖNTGENBILD DES SCHÄDELS

von

K. H. Schiffer

DYKE, DAVIDOFF und MASSON haben als neuroradiologische Symptome der Hemiatrophia cerebri u. a. einseitige Hyperplasien der paranasalen Höhlen und Verdickungen der gleichseitigen Schädelkalotte beschrieben. Solche einseitigen Nebenhöhlenhyperplasien kann man als Vacatkompensation von Hirndefekten (NOETZEL) interpretieren, die von Störungen in pränatalen oder postnatalen Stadien der Ontogenese herrühren; bei bilateralen Befunden ist die pathogenetische Interpretation schwieriger. Das Hauptproblem der Differentialdiagnose ist dabei die Abgrenzung von Befunden umschriebener und exogener Entstehung gegen Befunde, die z. B. von hormonellen Störungen abzuleiten sind, d. h. eher von generalisierten und endogenen Faktoren. Auch in der Phylogenese sind generelle Korrelationen zwischen der Entwicklung des Gehirns und der Pneumatisation des Schädels bekannt, die vor allem von WEIDENREICH und von DABELOW behandelt worden sind. Während bei Zwerghunden und bei Zwergaffen das in allometrischer Hinsicht grosse Gehirn nur von dünnen Deckknochen mit klaffenden Nähten umschlossen ist, wird z. B. beim Elefanten das — allometrisch gesehen — kleine Gehirn von umfangreichen Knochenteilen spongiösen Baus mit sehr grossen Luftkammerräumen umhüllt. Dadurch werden trotz der relativen Konstanz der Gehirnausmasse die Proportionen des Gesamtschädels denen des übrigen Körpers angeglichen. Es sei weiter an die symmetrische Über- bezw. Unterentwicklung der Nebenhöhlen bei der Akromegalie und dem angeborenen Kretinismus erinnert.

Fall 1. 27-j. hochwüchsiger Dysplastiker mit paranoider Psychose. Das Röntgenbild (Abb. 1) zeigt eine bilaterale Hyperplasie der Stirnhöhlen bei gleichfalls weiten Siebbeinzellbereich. Die Scheitelbeine sind seitengleich verdickt. Das Ventrikelsystem ist mittelständig, nur gering verplumpt mit leichter Betonung des rechten Seitenventrikels. In der Seitenaufnahme fand sich eine weite Sella, deren Boden tief in die Keil-

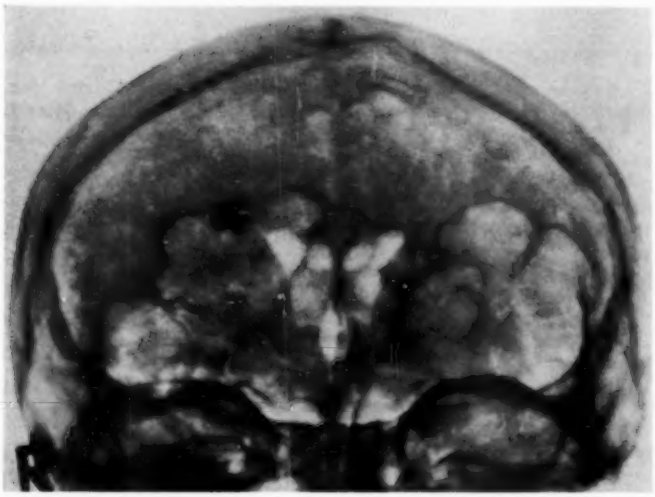

Abb. 1. Fall 1. Hochwüchsiger Dysplastiker. Bilaterale Stirnhöhlenhyperplasie, weiter Siebbeinzellbereich und seitengleiche Verdickung der Scheitelbeine.

beinhöhle reichte. Das Dorsum war auffallend schmal. Es bestanden keine Sehstörungen oder besondere neurologische Auffälligkeiten. Differentialdiagnostisch wurde hier eine zentrale Regulationsstörung nach frühkindlichem entzündlichen Prozess der Hirnbasis in Erwägung gezogen; weniger wahrscheinlich erschien die Annahme eines eosinophilen Adenoms.

Exakte Symmetrie bilateraler Befunde kommt aber nicht nur bei generalisierten oder sogar endogenen Faktoren, sondern auch bei Fällen mit höchstwahrscheinlich exogener Entstehung und als Ausdruck der Defektausfüllung vor. Offenbar bleibt die Symmetrie dann gewahrt, wenn der Schwerpunkt des Prozesses in der Symmetrieebene oder wenigstens in einer paramedianen Sagittalebene liegt oder aber wenn der exogene ätiologische Prozess von vornherein das ganze Organ gleichmässig betrifft.

Fall 2. 8-j. Knabe mit Schwachsinn nach wahrscheinlicher Meningoencephalitis im 1. Lebensjahr. Es bestand eine symmetrische, abnorme frühzeitige Ausweitung sämtlicher Nebenhöhlen. Im Encephalogramm zeigte sich eine hervorstechende Erweiterung des 3. Ventrikels im Rahmen eines leichten symmetrischen Hydrocephalus internus. Die Sella steht im Verhältnis zum Planum sphenoidale tief (Abb. 2) — ein Befund, der sich als Ausdruck einer Störung der Schädelbasisentwicklung ableiten lässt, wie in früheren Arbeiten gezeigt wurde. Die eigenartige Form der Sella wurde als »Rucksack-Sella« bezeichnet, weil die Sella wie ein Rucksack am Keilbeinkörper hängt. Starke Basisknickung.

Fall 3. 19-j. Patient mit juveniler Paralyse. Hier zeigte das Röntgenbild eine enorme symmetrische Ausdehnung der *zentralen* Gruppe der Nebenhöhlen. Die Sella war dysplastisch und hing rucksackartig am Keilbeinkörper. Starke Basisknickung.

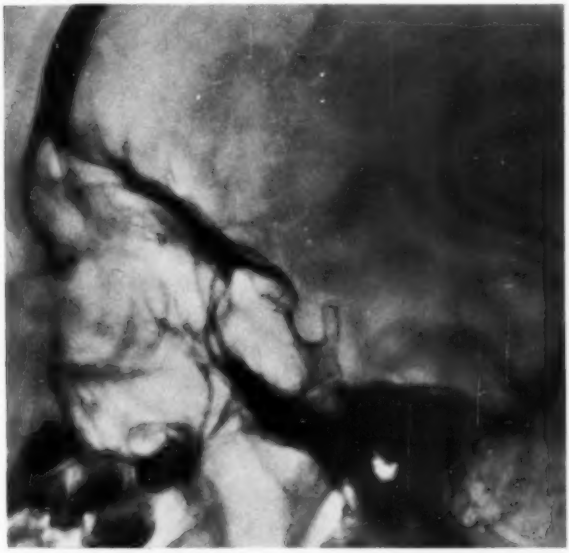

Abb. 2. Fall 2. 8-j. Knabe mit Schwachsinn. Vorzeitige Weite der Nebenhöhlen und »Rucksack-Sella«.

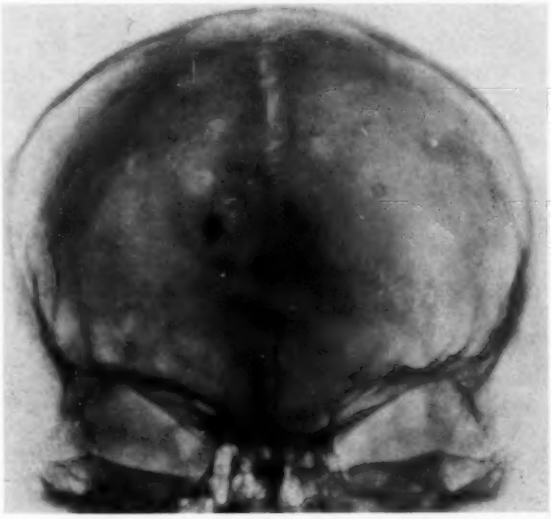

Abb. 3. Fall 4. 13-j. Knabe mit Schwachsinn. Weiter Siebbeinzellbereich, fast fehlende Stirnhöhlen, Hypertelorismus, steile Keilbeinflügel, sehr grosse und dünnwandige Kalotte, subkortikale Verkalkungen in beiden Hemisphären.

Abb. 4. Fall 5. 36-jährige Frau mit halbseitigen neurologischen Ausfällen. Einseitig ausladende und dünnwandige Schläfenschuppe, nach der gesunden Seite geneigte Crista Galli; auf der kranken Seite kleine Stirnhöhlen, stärker pneumatisierter Warzenfortsatz und multiple subkortikale Verkalkungen der Stammganglien.

Fall 4. Bei einem 13-j. Jungen mit Schwachsinn und Sprachentwicklungsstörungen infolge exogener Hirnschädigung finden sich mehrere subkortikal gelegene Verkalkungen in beiden Hemisphären (Abb. 3). Es besteht eine hervorstechende Erweiterung des Siebbeinzellbereiches, der einem Hypertelorismus mit einem Pupillenabstand von 64 mm entspricht. Die Stirnhöhlen fehlen praktisch. Die kleinen Keilbeinflügel steigen lateralwärts steil an, wie es beim Syndrom des Hypertelorismus als charakteristisch beschrieben wird. Schädelkalotte auffallend gross und abnorm dünnwandig, aber ohne Asymmetrie. Auf einem 6 Jahre früher durchgeführten Encephalogramm war nur eine geringe Erweiterung des linken Seitenventrikels zu erkennen, der rechte war eher zu schmal, der 3. Ventrikel sicher nicht erweitert. Das Ventrikelsystem ist mittelständig. Der Sabin-Feldmann-Test auf Toxoplasmose war positiv.

Pathologisch-anatomisch können wir hier multiple Cystenbildungen annehmen, die sich als raumfordernder Prozess auswirkten. HALLERWORDEN publizierte einen derartigen Befund mit multiplen subkortikalen Cysten beiderseits ohne nennenswerte Erweiterung der Ventrikel. Man kann sich zwanglos vorstellen, dass bei derartig vermehrter Raumerfüllung im Schädelinnern bei weitgehend geschlossenen Nähten die erst im 9.—12.-Lebensjahr erfolgende Grössenentfaltung des Stirnhöhlenbereiches nicht zustandekommt.

Abb. 5. Derselbe Fall als in Abb. 4. Hypoplasie des Mittelgesichts und Prognathie.

Von einem bilateralen Syndrom nach DYKE, DAVIDOFF und MASSON unterscheidet sich im letzten Falle der Befund durch die Hypoplasie der Stirnhöhlen und durch die Verdünnung und die Grösse der Kalotte. Diese, dem Syndrom von DYKE, DAVIDOFF und MASSON entgegengesetzten Befunde findet sich auch einseitig ausgebildet.

Fall 5. Bei einer 36-j. Frau mit seit früher Kindheit bestehender Epilepsie und einem rechtsseitigen Temporallappensyndrom zeigt das Röntgenbild (Abb. 4) eine starke Ausladung der Schädelkalotte im Schläfenbereich. Die Kalotte ist auf der kranken Seite dünner, kleiner Keilbeinflügel steigt gleichseitig steiler an, Crista Galli nach der gesunden Seite geneigt, Stirnhöhle auf der kranken Seite kleiner, während auf der kranken Seite der Warzenfortsatz eindeutig stärker pneumatisiert ist. Im Stammganglienbereich rechts finden sich multiple kleine Verkalkungen (Toxoplasmose-Test negativ). Im Arteriogramm liess sich eine meningiale Cyste im Schläfenbereich nachweisen. Das Encephalogramm zeigte eine Verschmälerung des rechten Seitenventrikels während der linke nur gering erweitert war. Keine Verlagerung des Ventrikelsystems über die Medianebene. Während also die Pneumatisation auf der kranken Seite ausgeprägter ist, kam es offenbar später infolge der Raumforderung nicht zu einer Erweiterung der Stirnhöhle auf der kranken Seite. Das Seitenbild (Abb. 5) zeigt eine Hypoplasie der Mittelgesichtspartie und eine fast anthropoid wirkende Prognathie.

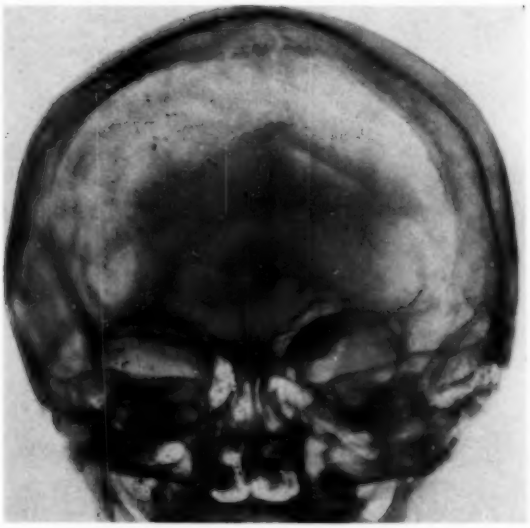

Abb. 6. Fall 7. 6-j. Mädchen mit Hemiatrophia cerebri nach Hirntrauma im 1. Lebensjahr. Vorzeitig entwickelte, ungewöhnlich grosse und auf der kranken Seite weitere Stirnhöhlen. Geneigte Crista Galli, und verdickte Kalotte an der kranken hypoplastischen Schädelhälfte.

Fall 6. Bei einer 34-j. Frau mit passageren Hirndrucksymptomen fand sich ein ganz ähnlicher Schädelbefund wie bei Fall 5. Die linksseitige Kalotte lud in der Schläfenregion stark aus und war dünner als rechts, auch stieg der kleine Keilbeinflügel links steiler an. Die Stirnhöhlen waren auf der gleichen Seite geringer ausgeprägt. Die Crista Galli war nach der gesunden Seite geneigt. Als Korrelat am Gesichtsschädel fand sich eine Vergrösserung und ein Hochstand der linken Orbita mit einseitigem Hypertelorismus.

Da sich die Nebenhöhlen aus Anteilen des Visceralcraniums entwickeln, ist eine Auswirkung von Verbildungen auf den Gesichtsschädel geradezu zu erwarten.

Im Syndrom von DYKE, DAVIDOFF und MASSON ist die räumliche Entwicklung der paranasalen Höhlen akzentuiert. Das Analogon der räumlichen Über- und Unterentwicklung ist in der Phylogenese, aber auch in der Ontogenese und in der Konstitutionsbiologie die Änderung des zeitlichen Ablaufs im Sinne der Propulsion oder Retardation. Bei den paranasalen Höhlen kann man auch eine vorzeitige Grössenentwicklung finden.

Fall 7. Bei einem 6-j. Mädchen liegt eine Hemiatrophia cerebri nach Hirntrauma im 1. Lebensjahr vor. Die Stirnhöhlen sind vorzeitig entwickelt, ungewöhnlich gross und auf der Seite der Hirnatrophie und Schädelhypoplasie eindeutig weiter (Abb. 6). Die Schädelkalotte ist auf der kranken Seite verdickt und die Crista Galli neigt sich nach der kranken Seite, das Felsenbein und der kleine Keilbeinflügel steigen lateralwärts stärker an. Auch steht die Orbita höher.

Befunde wie die von DYKE, DAVIDOFF und MASSON mitgeteilten und die anderen hier besprochenen Befunde, also z. B. mit Hyper- oder mit Hypoplasie der Stirnhöhlen, können noch vor dem Endstadium der Nebenhöhlenentwicklung für die neurologische Diagnose von frühkindlichen Hirnschäden von grosser Bedeutung sein.

Der Verfasser ist Herrn Prof. Dr. E. Kretschmer, Universitäts-Nervenklinik Tübingen für die Überlassung von Röntgenbildern zu aufrichtigem Dank verpflichtet.

ZUSAMMENFASSUNG

Es werden verschiedene Beispiele für die Auswertung von Röntgenbefunden am Schädel, besonders an den Nebenhöhlen, besprochen und mit dem Syndrom der Hemiatrophia cerebri nach DYKE, DAVIDOFF und MASSON verglichen.

SUMMARY

The evaluation of roentgenologic changes in the skull, particularly in the paranasal sinuses, are discussed and compared with the syndrome of cerebral hemiatrophy described by DYKE, DAVIDOFF, and MASSON.

RÉSUMÉ

Sur divers exemples l'auteur étudie l'interprétation de modifications radiologiques du crâne, et en particulier des sinus, et les compare au syndrome d'hémiatrophie cérébrale de DYKE, DAVIDOFF et MASSON.

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CLINIQUE NEURO-CHIRURGICALE DE LA PITIÉ (PROF. PETIT-DUTAILLIS), NEURO-RADIOLOGIE (DR. FISCHGOLD), PARIS, FRANCE

RADIOGRAPHIE SEGMENTAIRE DU CONDUIT AUDITIF INTERNE DANS LES NEURINOMES DE LA 8ÈME PAIRE

par

H. Fischgold, J. Metzger et *M. Juster*

Depuis 2 ans, 16 sujets avec une symptomatologie de neurinome de l'acoustique ont été radiographiés; la plupart provenaient de la Clinique Neuro-chirurgicale de La Pitié. Les examens furent aussi complets que le permettaient l'état du malade et le temps dont nous disposions; ils comprenaient les incidences conventionnelles, des incidences spéciales Stenvers et Chaussé IV, des agrandissements au tube de Van der Plaats et des tomographies. Parallèlement, des études de radio-anatomie agrandissante pratiquées sur des tranches de temporal sec ou des préparations sculptées complétèrent notre connaissance radiographique du conduit auditif interne et de ses confins (7). Cette double série de recherches mène à une description radiographique segment par segment du conduit auditif interne dans les neurinomes de l'acoustique; montre l'extension intra-pétreuse des lésions destructives; soulève l'espoir d'un diagnostic précoce.

La radio-anatomie du conduit auditif interne nécessite quelques précisions: il ne paraît plus possible de considérer le conduit long de 7 à 8 millimètres et haut de 3 à 4 millimètres (Hovelacque) comme une formation unique.

On attribue au conduit auditif interne les quatre segments suivants: la gouttière creusée sur la face postérieure du rocher; le pore (ou orifice) marquant l'entrée du canal; le canal proprement dit avec ses quatre parois: toit, plancher, parois antérieure et postérieure; le fond divisé par deux crêtes perpendiculaires en quatre fossettes: faciale, cochléenne, vestibulaires supérieure et inférieure.

Les rapports du conduit auditif interne sont également importants: rapports du pore avec la citerne ponto-cérébelleuse; de la gouttière avec le tiers interne et la pointe du rocher; du canal avec le limaçon et la carotide interne; du fond avec le vestibule et la cochlée.

De ces recherches radio-anatomiques seront relevées les constatations radiographiques concernant le fond du conduit auditif interne: la figure 5 et sa légende illustrent ces données et constituent la meilleure initiation dans l'interprétation des radiographies prises sur le vivant.

Il est inutile de reprendre en détail la technique radiographique. C'est plutôt l'évolution des techniques qui intéresse. Trois noms se détachent.

HENSCHEN décrivait en 1911 le neurinome de l'acoustique comme une poire dont la queue est attachée au nerf vestibulaire à l'intérieur du canal: l'extrémité effilée élargit le pore, tandis que la masse principale se développe dans la citerne ponto-cérébelleuse. HENSCHEN conclut de ses recherches que le conduit auditif interne est modifié pour tout neurinome de l'acoustique suffisamment avancé et que la radiographie doit trouver ces modifications. Il publie, à la fin de son travail, la première radiographie pratiquée par FORSSELL d'un conduit auditif interne élargi, dans un neurinome de l'acoustique (6).

En regardant les dessins de HENSCHEN, on comprend qu'il n'y ait pas de parallélisme entre les modifications radiographiques du conduit auditif interne et les dimensions de la tumeur vue par le chirurgien, derrière le rocher, dans la citerne ponto-cérébelleuse.

STENVERS a trouvé une incidence qui projette le conduit auditif interne avec son grand axe parallèle au film. Il a publié les premières radiographies de conduit auditif interne élargi par le neurinome de l'acoustique; il a démontré sur ses radiographies le développement intra-pétreux du neurinome vers la pointe du rocher. La radiographie du neurinome de l'acoustique constitue donc la découverte fondamentale de STENVERS et sa monographie de 1928 conserve encore son actualité (10).

L'incidence IV de CHAUSSÉ part de la notion qu'il n'est pas possible d'obtenir tout le rocher avec une égale netteté par une seule incidence. L'incidence IV dégage le conduit auditif interne, la cochlée et la pointe du rocher et laisse en pénombre le labyrinthe et la mastoïde (2, 3). Nous lui devons une notion nouvelle qui ne gagne que trop lentement du terrain: toute incidence radiographique, aussi correcte qu'elle soit, ne fournit qu'une image 'moyenne'. Pour radiographier une formation, un segment ou un élément, et compte-tenu des variantes individuelles, il faut 'balayer' avec le rayon en modifiant de quelques degrés son inclinaison. On rend ainsi le rayon incident tangent à une crête (falciforme p. ex.), ou normal à un orifice (du canal de Fallope), ou à une fossette (comme la

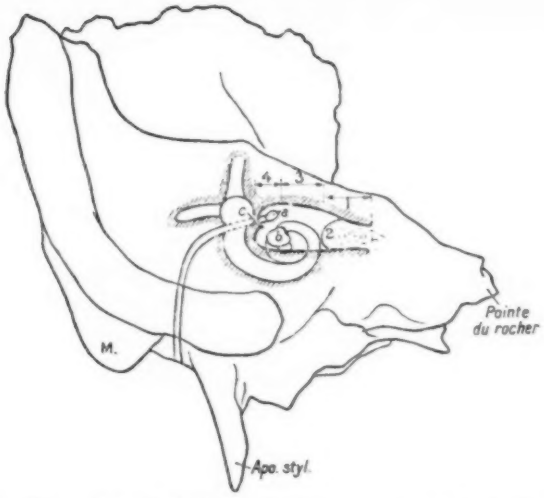

Fig. 1. Schéma du conduit auditif interne avec ses 4 portions: 1. gouttière (*sulcus*); 2. pore (*porus*); 3. canal (*canalis*); 4. fond (*fundus*). a = fossette et première portion de l'aqueduc de Fallope; b = fossette cochléenne; c = crête falciforme.

fossette cochléenne). CHAUSSÉ a complété les notions d'incidence et de balayage par celle de cliché 'étalon'. Un cliché radiographique est valable s'il contient l'information cherchée: une «incidence STENVERS» sur laquelle on ne détache pas bien le conduit auditif interne n'est pas utilisable même si elle a été pratiquée selon la 'bonne règle'. L'étalon rappelle à chaque instant le but anatomique du cliché.

Selon les auteurs de ce travail, une radiographie complète du rocher dans le neurinome de l'acoustique doit permettre une étude détaillée des segments du conduit auditif interne (Fig. 1). Il ne suffit pas d'obtenir de 'bons clichés'. Il faut visualiser le conduit auditif interne avec le minimum de déformation et le maximum de détail, segment par segment.

Cette visualisation — segment par segment — n'est possible que par des incidences et balayages multiples, par des pénétrations variables; ainsi les différentes images se recoupent et donnent au radiologiste entraîné une représentation très complète du conduit auditif interne normal, modifié ou détruit par la tumeur.

Dès qu'on vise un segment du conduit auditif interne et non sa totalité, les incidences perdent leur vertu exclusive; car chaque segment du conduit auditif interne aura ses incidences propres.

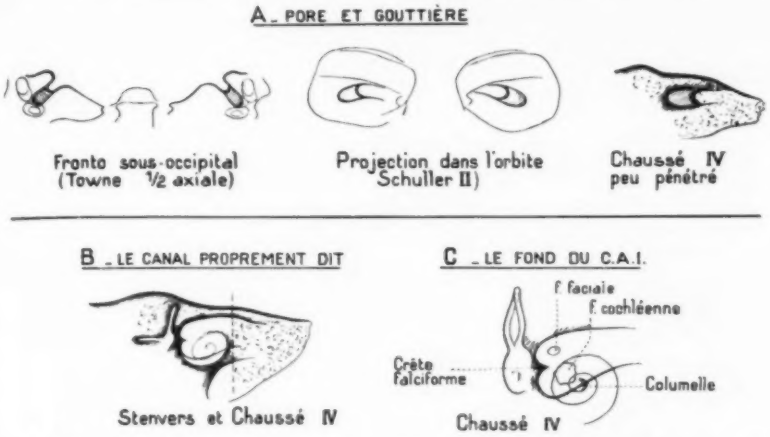

Fig. 2. Incidences et radios-étalons des 4 segments du conduit auditif interne (C. A. I.).

Pore et gouttière se dégagent le mieux sur l'incidence fronto-sous-occipitale (demi-axiale) ou sur les rochers projetés dans l'orbite (SCHÜLLER II); sur le CHAUSSÉ IV on les retrouve à condition de ne pas trop pénétrer le cliché (Figs. 2A et 3).

Dès que le limaçon, le canal carotidien, le conduit auditif interne dans sa totalité se dégagent sur l'incidence de CHAUSSÉ IV, la lèvre postérieure du pore s'efface; on peut encore le situer grâce à une ligne tracée à l'intérieur de la couronne cochléaire entre l'os homogène du canal et l'os spongieux de la gouttière (Fig. 2B).

Le canal avec son toit et son plancher se retrouve sur le STENVERS et le CHAUSSÉ IV; l'agrandissement $\times 2$ le montre limité par de l'os compact; le liséré des parois reste en continuité avec la corticale du conduit et du labyrinthe; autour de cette masse dense (corticale, labyrinthe, canal) se déploient l'os spongieux ou pneumatisé et le canal carotidien (Fig. 4).

Le fond du conduit auditif interne se dégage le mieux par des 'balayages' autour du CHAUSSÉ IV et une pénétration suffisante pour définir les différents éléments contenus dans la coque compacte du labyrinthe; avec un agrandissement $\times 2$ on découvre: la cloison osseuse, mince et dense, qui sépare le fond du conduit auditif interne du vestibule; la crête falciforme; la fossette du canal de Fallope; la fossette cochléenne projetée sur la partie supéro-externe du limaçon, comme une clarté à contours rhomboïdes; la columelle au centre du limaçon (Figs. 2C, 4 et 5).

On reconnaît ces éléments encore mieux dans certains cas pathologiques où la compacte qui entoure le conduit auditif interne a perdu sa densité, où le fond du conduit est élargi mais non détruit.

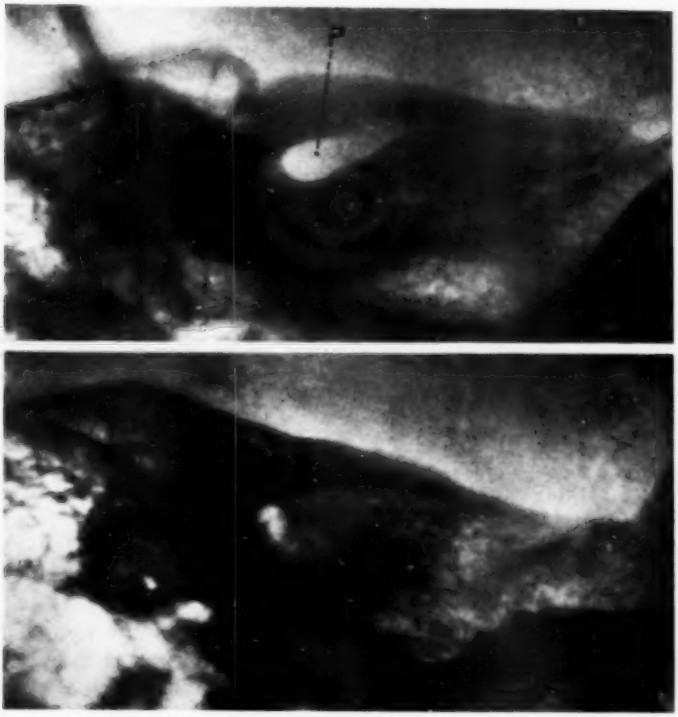

Fig. 3. (*En haut*). Incidence CHAUSSÉ IV à faible pénétration. Agrandissement × 2. P = le pore.

Fig. 4. (*En bas*). Conduit auditif interne en incidence STENVERS-CHAUSSÉ IV. Agrandissement × 2. Le conduit proprement dit est constitué d'os homogène. Le pore et la gouttière commencent avec l'os spongieux.

L'incidence axiale ou vertex-plaque a été systématiquement pratiquée; elle nous paraît encore d'interprétation difficile et ne sera vraiment utile qu'après une mise au point par 'balayage'.

La tomographie n'ajoute rien dans l'examen d'un rocher normal; les finesses révélées par l'agrandissement se perdent totalement, mais elle devient indispensable pour suivre l'infiltration et l'extension du neurinome à l'intérieur du rocher et vers le trou déchiré postérieur. Cette extension intra-pétreuse, étudiée en détail par GRAF était encore considérée comme invisible aux rayons röntgen par des observateurs aussi avertis que BRÜNNER en 1935.

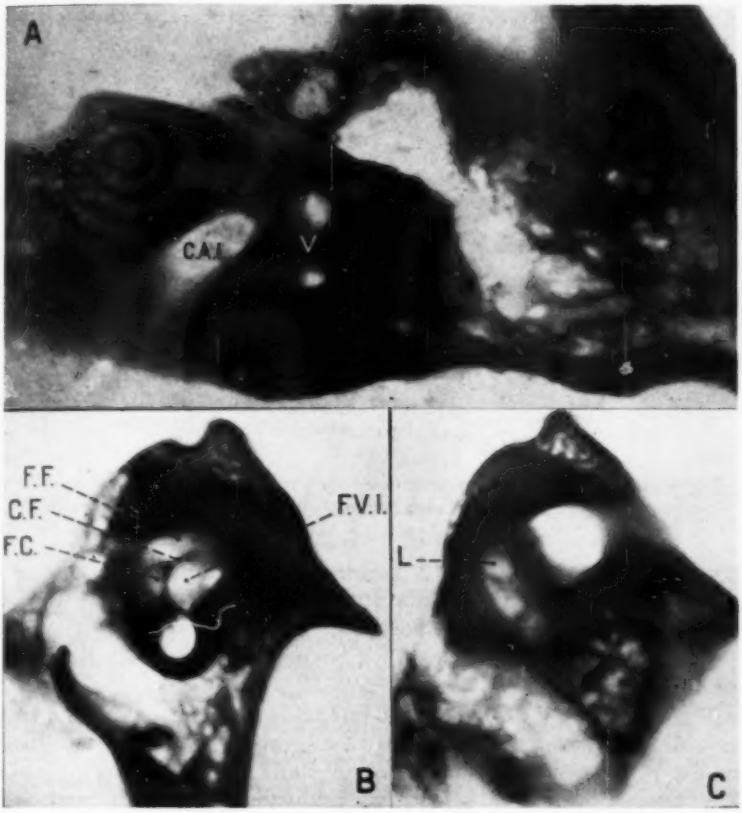

Fig. 5. Étude radio-anatomique du conduit auditif interne. Agrandissement × 2. A. Coupe horizontale. C. A. I. = conduit auditif interne; V = vestibule. B. Coupe suivant l'incidence de SCHÜLLER et montrant le fond du conduit auditif interne. F. F. = fossette du facial; C. F. = crête falciforme; F. C. = fossette cochléenne; F. V. I. = fossette vestibulaire inférieure. C. Coupe suivant l'incidence de SCHÜLLER. L = limaçon.

Sur les 16 observations que nous avons étudiées, 11 seulement feront l'objet d'un exposé plus complet, ceci pour éviter des redites.

Sur ces 11 cas, 8 ont été vérifiés opératoirement: 7 fois, le neurochirurgien a trouvé le neurinome dans l'angle ponto-cérébelleux, 1 fois il n'a trouvé qu'un kyste séreux; les 2 cas de neurofibromatose de Recklinghausen ont été vérifiés histologiquement; 1 cas n'a pas encore été opéré.

Ces 11 observations sont groupées selon la classification de CHAUSSÉ.

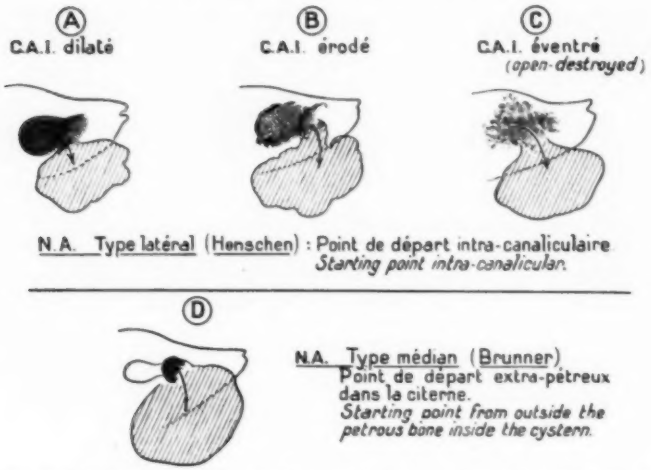

Fig. 6. Types et développement du neurinome de l'acoustique. C. A. I. = conduit auditif interne; N. A. = neurinome de l'acoustique.

D'après cet auteur, l'action du neurinome de l'acoustique sur le conduit auditif interne s'exerce de trois manières différentes qui constituent autant d'étapes évolutives (Fig. 6):

1) le neurinome dilate le conduit auditif interne dont les contours restent conservés;

2) le neurinome dilate le conduit auditif interne en modifiant l'aspect du pore et en altérant les parois du canal, érodées ou hypertrophiées; le neurinome reste néanmoins 'emprisonné' dans le conduit auditif interne;

3) le neurinome dilate le conduit auditif interne dont les contours sont partiellement ou totalement détruits; mais la tumeur 'éventre' le conduit auditif interne et se développe dans le rocher.

Cependant, quel que fut le stade du développement intrapétreux, le neurinome était aussi présent dans la citerne ponto-cérébelleuse; c'est d'ailleurs la grande masse développée dans la citerne, visible seulement par encéphalographie gazeuse, comprimant le tronc cérébral et les paires nerveuses V, VII et même IX, X et XI, qui amène un 'sourd' de longue date chez le neuro-chirurgien.

Sur les 7 neurinomes de l'acoustique trouvés par le neuro-chirurgien 1 fois seulement le pore seul était dilaté; 1 fois le pore et le canal étaient dilatés, mais le fond restait intact; 5 fois le conduit auditif interne était dilaté (ou détruit) dans sa totalité.

Sur les 8 malades dont la tumeur a éventré le rocher, l'infiltration s'est faite: 3 fois vers le bord supérieur, 2 fois vers la pointe, 2 fois vers

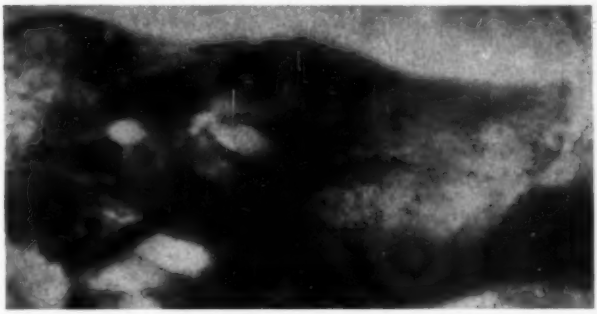

Fig. 7. CHAUSSÉ IV agrandi. Rocher droit (comparer avec la Fig. 4, côté gauche de la même malade). Erreur de diagnostic: pas de neurinome. Au fond du canal dilaté la fossette de Fallope en haut; la fossette cochléenne se détache en bas comme une clarté superposée au limaçon et à la columelle. Les parois étant partout intactes, la dilatation ne suffit pas pour porter le diagnostic de neurinome de l'acoustique.

le trou déchiré postérieur, 1 fois vers le vestibule, 1 fois vers le bord supérieur et vers le trou déchiré postérieur.

La conception fondamentale de HENSCHEN sur le développement du neurinome de l'acoustique reste valable pour la grande majorité des cas: le neurinome naît sur le segment latéral (distal ou externe) du nerf vestibulaire, à l'intérieur du canal, s'écoule selon une ligne de moindre résistance à travers le pore et développe sa masse principale en dehors du rocher dans la citerne ponto-cérébelleuse (Fig. 6, A—C).

Pour un nombre plus réduit de neurinomes de l'acoustique, il y a lieu d'introduire le type de BRÜNNER; le neurinome naît sur le segment médian

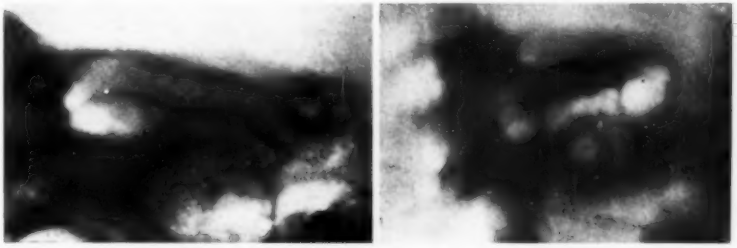

Fig. 8. Neurinome de l'acoustique droit (type HENSCHEN). *A gauche:* STENVERS-CHAUSSÉ IV. Agrandissement × 2. Conduit auditif interne fortement dilaté vers le haut. Bonne visibilité de la crête falciforme et des fossettes. *A droite:* Tomographie en STENVERS. Le conduit auditif interne est éventré vers le haut, entouré d'une zone de condensation.

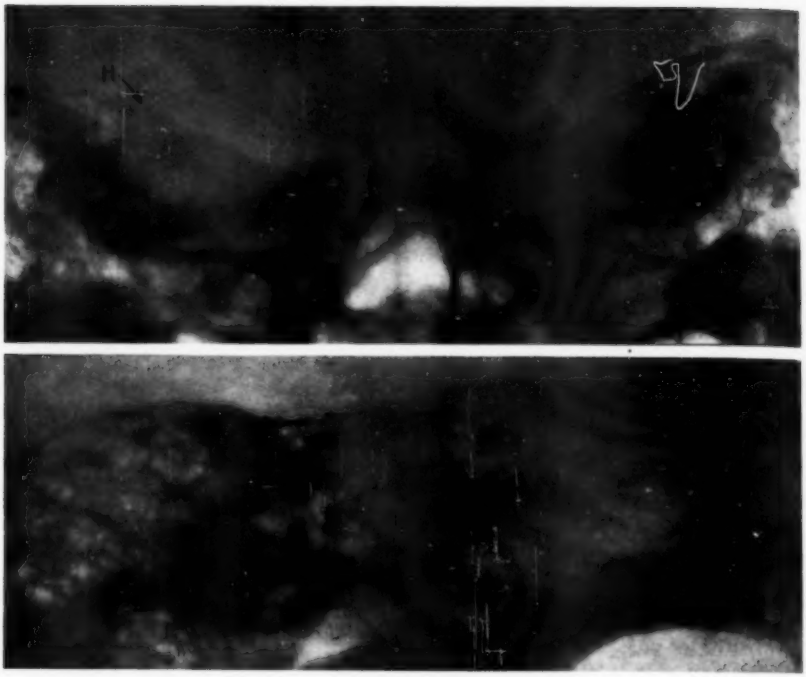

Fig. 9. Neurinome de l'acoustique droit (type HENSCHEN). *En haut:* Incidence de TOWNE. A droite, destruction de tout le conduit auditif interne; hernie cérébrale (H); à gauche, conduit auditif interne dilaté par hyperpression. *En bas:* CHAUSSÉ IV. Agrandissement × 2. Destruction de tout le conduit auditif interne, y compris le fond. Les clartés des fossettes et celle du vestibule ne sont séparées par aucune cloison. Le limaçon n'est plus visible.

(proximal ou interne) de la 8ème paire, poursuit sa croissance toujours en dehors du rocher et détermine une compression du tronc cérébral avant que les nerfs cochléaire et vestibulaire soient totalement détruits et la citerne ponto-cérébelleuse altérée; ce n'est qu'à la période tardive que la néoformation érode le pore d'arrière en avant, tout en laissant le canal intact (Fig. 6, D).

Sur les 7 cas de neurinome de l'acoustique vérifiés par le neurochirurgien, 6 fois la tumeur avait une origine latérale, type HENSCHEN; 1 seule fois le neurinome avait une origine médiane type BRÜNNER; c'était d'ailleurs la seule observation où seul le pore était atteint.

Ces considérations expliquent pourquoi la grande majorité des neurinomes de l'acoustique, au stade tardif auquel ils viennent chez le neuro-

Fig. 10. Neurinome de l'acoustique droit (type HENSCHEN). Tomographie en position de STENVERS. Destruction totale du conduit. Le neurinome a éventré le conduit auditif interne et s'est développé vers le trou déchiré postérieur. G. J. = golfe de la jugulaire; C. XII = canal de l'hypoglosse.

chirurgien, s'accompagnent de modification du rocher sur les radiographies.

Tel est le cas dans la statistique de LUNDBORG du Service LINDGREN: sur 296 observations de neurinomes de l'acoustique opérés, les signes radiographiques existaient sur le rocher atteint dans 85 % des cas. Dans notre série, 7 fois sur 7, le neurinome était accompagné de lésions du rocher.

Malgré une dilatation importante du conduit auditif interne, il n'y avait pas de neurinome; ceci prouve qu'on doit se méfier des simples variations de calibre et des asymétries modérées des 2 conduits auditifs internes; STENVERS avait déjà signalé cette cause d'erreur dès 1928.

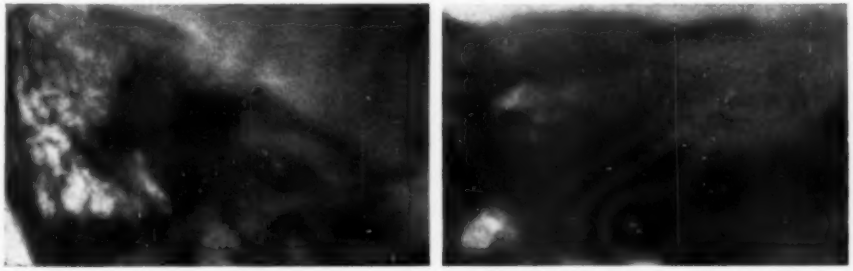

Fig. 11. Neurinome de l'acoustique droit (type BRÜNNER). *A gauche:* Incidence de TOWNE. Elargissement du pore. Conduit auditif interne peu visible. *A droite:* STENVERS-CHAUSSÉ IV. Agrandissement × 2. Le canal proprement dit ainsi que le fond du conduit auditif interne sont intacts. Pore difficile à délimiter par rapport à la spongieuse de la gouttière.

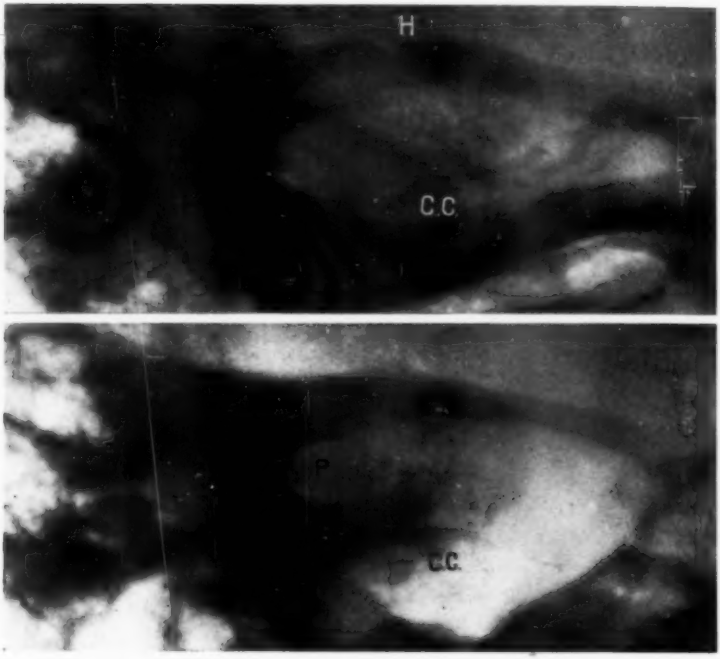

Fig. 12. Maladie de Recklinghausen. Neurinome de l'acoustique bilatéral. *En haut:* (type Henschen) Stenvers-Chaussé IV. Agrandissement × 2. Destruction complète du conduit auditif interne jusqu'au canal carotidien (C. C.). Il persiste un secteur de clarté au niveau du limaçon. Vestibule également invisible. Hernie du rebord supérieur (H). *En bas:* (type Brünner) conduit auditif interne intact. Le pore (P) est très bien visible. Le neurinome, développé initialement dans la citerne postérieure, s'est développé dans la gouttière et la pointe, qui apparaît totalement évidée.

Ceci nous permettra de conclure sur trois points fondamentaux.

A condition que la technique radiographique soit rigoureuse, la grande majorité des neurinomes de l'acoustique type Henschen altère le conduit auditif interne; les auteurs qui prétendent le contraire emploient le terme ambigu de 'radiographie négative', sans prouver qu'ils avaient obtenu sur leurs clichés le conduit auditif interne dans sa totalité avec bonne visibilité des trois segments.

La technique radiographique actuelle (incidences multiples particulièrement Stenvers et Chaussé IV) comprenant l'agrandissement radiographique direct × 2 et la tomographie permet une analyse segmentaire du conduit auditif interne et une étude du développement intra-pétreux du neurinome de l'acoustique. Cette dernière notion est

destinée à intervenir dans la discussion de la cure radicale ou de la récidive du neurinome de l'acoustique; les neuro-chirurgiens sont peut-être trop enclins à voir dans le neurinome de l'acoustique seulement la grosse masse développée dans la citerne ponto-cérébelleuse.

Nous terminerons sur une question qui rejoint les préoccupations de HENSCHEN d'il y a plus de 40 ans: le diagnostic radiographique du neurinome de l'acoustique au stade précoce purement intra-pétreux est-il possible? Probablement oui pour le type HENSCHEN; pour le type BRÜNNER, l'encéphalographie gazeuse reste la méthode de choix vu les difficultés que présente encore l'angiographie vertébrale.

Quel que soit le type, quelle que soit la technique neuro-radiographique, cette question se déplace d'emblée: le neurinome du 8, au stade précoce est du domaine des otologistes comme l'a montré récemment LUNDBORG; c'est à la technique otologique de déceler derrière une baisse d'audition une petite tumeur intra-pétreuse déjà visible, dans certains cas, sur les clichés radiographiques.

Un tel diagnostic précoce — s'il était possible — obligerait d'ailleurs le chirurgien à repenser le problème de l'exérèse et des voies d'abord de la tumeur.

RÉSUMÉ

Les auteurs utilisent leurs études de radio-anatomie et les techniques radio-otologiques de STENVERS et CHAUSSÉ complétées par: l'agrandissement direct × 2, la tomographie, et les pénétrations variables.

Ils ont examiné 16 malades suspects de neurinome de l'acoustique. Ils distinguent des neurinomes qui dilatent le conduit, détruisent les parois tout en restant emprisonnés dans le canal, ou ceux qui l'éventrent. Ceci est valable pour les neurinomes latéraux externes, type HENSCHEN, à point de départ intra-pétreux. Pour les neurinomes médiaux ou internes, type BRÜNNER, à point de départ extra-pétreux, seuls la gouttière et le pore sont modifiés au stade tardif.

Dans ces conditions, sur 8 neurinomes opérés, 7 du type HENSCHEN et 1 du type BRÜNNER, les modifications radiographiques étaient toujours présentes.

SUMMARY

Radio-anatomic studies, the radio-otologic techniques of STENVERS et CHAUSSÉ together with direct magnification × 2, tomography and variable penetrations were used in the authors' examinations of 16 patients with suspected acoustic neurinoma. Distinction is made between neurinomas, which dilate the canal and destroy its walls but remain confined in the canal, and neurinomas which extend outside of the porus. This applies to the lateral external neurinoma, type HENSCHEN, of intrapetrous origin. The medial or internal neurinoma, type BRÜNNER, of extrapetrous origin, involves only the groove and modifies the porus in a later stage. Roentgenographic changes were confirmed in 8 cases operated upon, 7 of type HENSCHEN and one of type BRÜNNER.

ZUSAMMENFASSUNG

Bei der Untersuchung von 16 Patienten mit suspekten Akustikusneurinomen benutzen die Verfasser anatomische Studien und die röntgenologische Untersuchungstechnik von STENVERS und CHAUSSÉ, welche sie mit zweifacher Bildervergrösserung, Tomographie und variabler Strahlenhärte komplettierten. Sie unterscheiden zwischen Neurinomen, welche den Akustikuskanal erweitern und dessen Wände destruieren, aber innerhalb des Kanales begrenzt bleiben, und den Neurinomen, welche sich ausserhalb des Porus ausbreiten. Letzteres gilt für die lateralen externen Neurinome, Typus HENSCHEN, die innerhalb des Os petrosum entstehen. Die medialen oder inneren Neurinome, Typus BRÜNNER, die extrapetrös entstehen, engagieren nur den Sulcus und verändern den Porus erst in einem späteren Stadium. Die röntgenologischen Befunde sind in 8 Fällen operativ bestätigt worden; sieben waren vom Typus HENSCHEN und einer vom Typus BRÜNNER.

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THE ANTERIOR CHOROIDAL ARTERY

by

S. E. Sjögren

The anterior choroidal artery has so far not been given much attention in the literature. In recent years it has been mentioned sporadically, mostly in connection with individual cases, *e. g.* by ECKER, but it has not been possible to find a systematic description of its roentgenologic anatomy and its changes in pathologic conditions. For that reason, a more detailed investigation has been carried out in the Roentgen Department of Serafimerlasarettet. This has been based upon 30 specimens and 100 carotid angiographies in patients without clinical or roentgenologic signs of expanding or atrophic intracranial lesions. At the same time, the pathologic changes have been studied in about 400 carotid angiographies. In both series a comparison has been made between angiography and pneumography in the same patient.

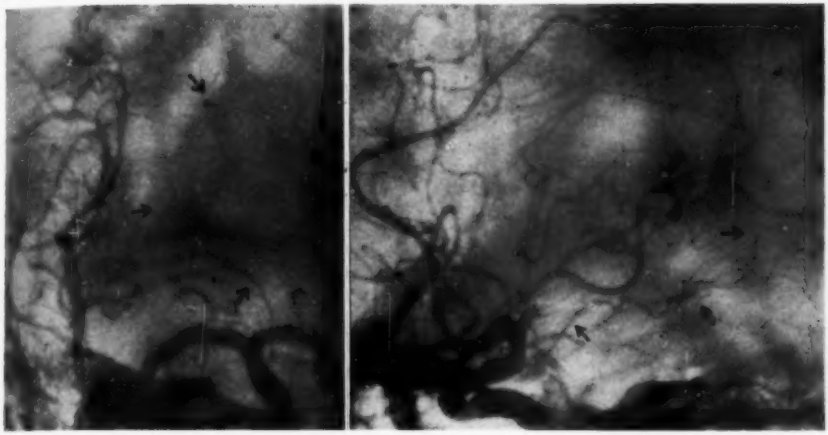
In typical cases the anterior choroidal artery issues from the posterior aspect of the carotid siphon just above the posterior communicating artery. The distance from the bifurcation of the internal carotid artery varies, and on an average is about 0.5 cm. The anterior choroidal artery could be identified both in a. p. and lateral views in 93 out of the 100 normal angiographies. In 88 cases it seemed to arise from the posterior aspect of the siphon, in 2 from the middle cerebral, and in 3 from the posterior communicating artery. Additional arteries to the plexus were probably present in a few cases. These findings correspond well with those of MORELLO and COOPER, who were able to demonstrate the anterior choroidal artery in 92 out of 100 lateral views of normal cases. They found it to originate from the middle cerebral artery in one case, from the posterior communicating artery in 8, and from the internal carotid artery in the rest of the cases. In an anatomic investigation of 60 hemispheres, CARPENTER, NOBACK and MOSS found the anterior choroidal artery to arise "from the internal carotid artery in 76.6 %, from the middle cerebral artery in 11.7 %, from the posterior communicating artery in 6.7 %,

Fig. 1. Photograph from above of basal part of brain divided by horizontal section through the temporal horn. Anterior choroidal artery (arrows) circumvents uncus, passes through crural and ambient cisterns to plexus in supracornual cleft of temporal horn. Hippocampus bulges into supracornual cleft from below with lateral cleft outside it.

and from the junction of the anterior and middle cerebral arteries in 3.30 %". It was absent in one case. They thus found it to originate from the middle cerebral artery considerably more frequently than seen in angiograms. This is probably due to the difficulty in some cases to decide from films whether the artery arises from the uppermost part of the internal carotid artery or from the first part of the middle cerebral artery. Oblique views might have helped but were not used. METTLER's statement that the anterior choroidal artery arises from the middle cerebral artery as frequently as from the internal carotid artery does not, on the other hand, agree with either of these investigations.

The topography of the anterior choroidal artery is in anatomic specimens best studied from a horizontal section of the brain through the temporal horn (Fig. 1). The first part of the artery lies in close connection with the medial and posterior surfaces of the uncus. It therefore describes a curve with a medial convexity, passing through the space between the uncus and the cerebral peduncle, the crural cistern. It continues laterally across the anterior part — the wing — of the ambient cistern to the choroidal plexus in the temporal horn. The portion of the artery just described will be called the cisternal part. The rest of the artery lies in the choroidal plexus, and this will be referred to as the plexal part. There are many reasons for considering the vessel from its origin to the body of the lateral ventricle as one unit. In most cases the cisternal part continues directly in the plexus and this continuation is thicker than the branches. In pathologic cases it is essential to consider the whole artery.

The artery enters the plexus in the supracornual cleft of the temporal horn at or just behind the level of the 'knee' of the horn, *i. e.* the point where the supracornual cleft begins to bend down over the pes hippocampi. Only a short tip of the plexus lies in front of the entrance. The



a b

Fig. 2. Normal carotid angiography. Anterior choroidal artery in (a) half-axial and (b) lateral views. In both projections the plexus can be followed up into body of lateral ventricle.

artery divides immediately after entering the plexus, resulting in a network of tortuous vessels. In Fig. 1, the main artery is seen lying close to the medial edge of the plexus. In the temporal horn the artery changes from a lateral to an oblique, and then to a direct posterior direction. The plexus continues in a curve up through the trigone into the body of the lateral ventricle; in the trigone, it receives the lateral posterior choroidal artery.

In half-axial a. p. views in carotid angiography, the anterior choroidal artery has about the same appearance (Fig. 2a) as in specimens of the type shown in Fig. 1. It usually emerges in a typical way on the medial side of the carotid artery before its bifurcation. The plexal part in this region may in most cases be followed up through the trigone. It has a sinuous course and several branches may be seen. The anterior tip of the plexus is also visible; it has an oblique antero-medial direction. Some, not infrequent cases also have another fairly large artery along the lateral border of the plexus. Contrast filling of the arteries and a more diffuse filling of the plexus are often present in the same film; the latter may often be observed in the venous phase.

In normal cases the origin of the anterior choroidal artery is usually situated more basally than its entrance in the temporal horn. In lateral views the cisternal part is then seen to run in a main direction obliquely backwards and somewhat upwards (Fig. 2b) to a point within the normal

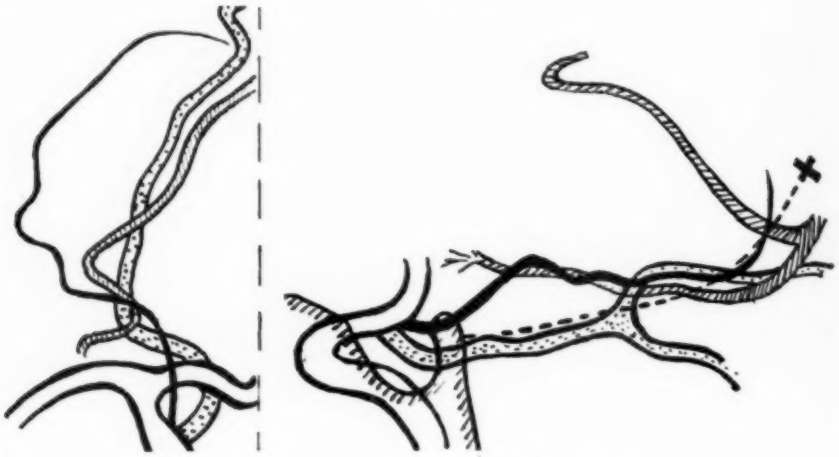


Fig. 3. Sketch showing relationships between anterior choroidal artery (full line), internal cerebral veins (striped line), and posterior communicating and posterior cerebral arteries (dotted line), in half-axial and lateral projections. Interrupted lines represent midline and edge of tentorial notch.

variation of the position of the knee of the temporal horn. Except for these conditions, the cisternal part varies in shape from case to case. It is usually S-shaped, but sometimes arched. However, in normal cases I have not found it to be either quite straight or sharply kinked. The point where the artery enters the plexus can generally be identified. It lies at the knee of the temporal horn, or sometimes just behind it. There it may be seen to divide, and it is often surrounded by the more or less diffuse contrast filling of the plexus. The continued course of the artery corresponds to the shape of the temporal horn and the trigone. The contrast medium in the plexus appears often as a string of small clots.

Knowledge of the normal topographic relations between the anterior choroidal artery, the posterior communicating and posterior cerebral artery, and the basal vein, is valuable for an understanding of pathologic changes in certain cases, *e. g.* in tentorial down-herniations. These relationships are shown in the sketches in Fig. 3, which are based on tracings of 20 normal angiograms. In typical cases the basal vein runs above the uncus, the anterior choroidal artery crosses its medial surface, and the posterior communicating and posterior cerebral artery is on a level with, or below its inferior border. The basal vein and the anterior choroidal artery cross behind the uncus, the vein running along the brainstem. Having passed through the crural cistern, the posterior communicating

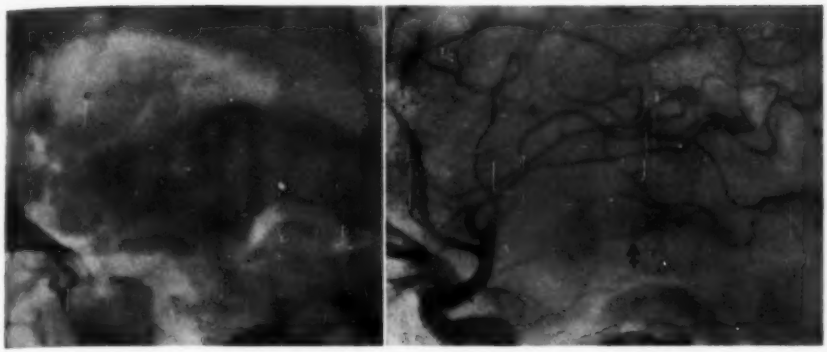


Fig. 4. Temporal horn pushed backwards by expanding lesion. Plexus deformed in identical manner and cisternal part of anterior choroidal artery stretched. The point where the plexus begins is evident (!).

artery takes the same main direction, but usually it has not the same close connection with the stem as the vein, and in some cases makes a loop into the ambient wing. In lateral views, the temporal part of the plexus is on about the same level as the basal vein, separated from it by the wing of the ambient cistern. Anteriorly, the posterior communicating artery runs a little more basally but posteriorly on the same level.

The 100 normal angiographies were selected at random from our material, but 3 cases in which the definition of the films was poor were replaced by others. Thirty examinations were performed with rapid serial angiography and 70 with the conventional technique. It was possible to identify the anterior choroidal artery both in a. p. and lateral views in 93 cases, in 4 in only one projection, and in 3 in neither one. In the majority of cases, it was easy to recognize the vessel, including part of and often the entire plexus. The identification was, however, difficult in some cases, especially in lateral films. It was thus sometimes difficult to distinguish the anterior choroidal artery from the numerous other small arteries in this region. It was therefore sometimes better to identify the choroidal plexus first, and then follow the cisternal part backwards. In the study of fine vessels, the technique obviously plays an important part; the figures quoted above thus tell us nothing about the anatomical conditions in the unsuccessful cases. The difficulties are certainly mainly due to technical factors. Apart from good quality — particularly high definition — the films must have been exposed in the correct phase. Contrast filling of the anterior choroidal artery begins and reaches its maximum earlier than in other arteries, and the contrast

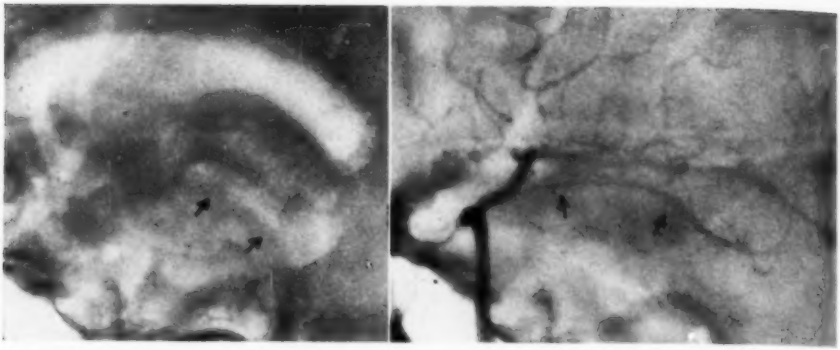
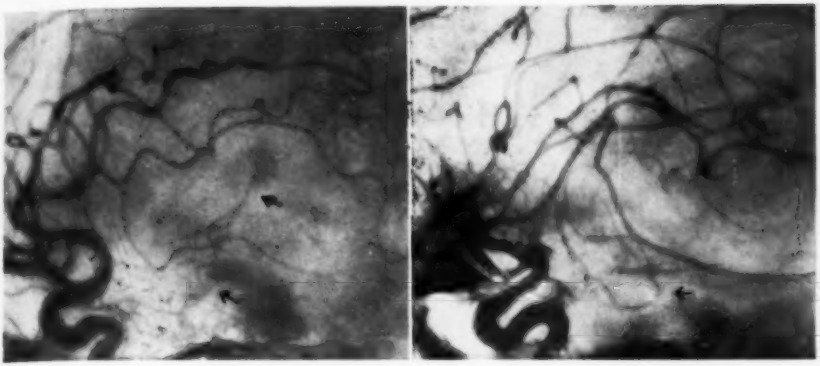


Fig. 5. Elevation of anterior part of temporal horn by basally situated tumour (chordoma). Corresponding displacement of choroidal plexus and secondary change in cisternal part.

medium also disappears much earlier. Consequently, it had probably sometimes begun to empty when the first exposure was made in routine examinations. In rapid serial angiography, on the other hand, it is always possible to pick out a film with maximum contrast filling of the anterior choroidal artery. Identification of the vessel was made without difficulty in all 30 cases of rapid serial angiography. Another reason for examining the anterior choroidal artery at the beginning of the arterial phase is that many of the arteries with which it might be confused, or obscured by, have by then not been filled.

The changes in the anterior choroidal artery in cases with intracranial expanding lesions have been studied in a material of about 400 angiographies, mainly cases with tumours not too distant from the temporal region. Excluding cases in which the films were of poor definition, it was possible, or difficult, to identify the vessel in about the same proportion as in the normal material. It was facilitated as the anterior choroidal artery in the pathologic cases were on the average wider than normal, particularly when stretched. Upward displacement of the arteries in the Sylvian fissure made the reading of lateral views easier, while many other forms of vascular displacement increased the difficulties, and sometimes made confusion possible. To have more than one a. p. view exposed with a somewhat different tilt of the tube, was always a distinct advantage. In about three-quarters of the cases both angiography and pneumography were carried out, and a comparison was made by means of superimposing transparencies of the two types of examinations. The primary object of interest was to investigate if any conclusions could be drawn regarding the location of the temporal horn from the appearance of the artery in



a b

Fig. 6. Posteriorly situated tumours: a) in basal position, elevating and pushing forwards posterior part of choroidal plexus; b) in higher position, compressing the plexal and cisternal parts.

cases with different types of displacements of the temporal horn. The result is largely based on the possibility of identifying the point where the plexus begins. It could as a rule be demonstrated in lateral films, and generally proved to be more evident in pathologic cases, especially when the temporal horn was displaced backwards. This is probably due to the plexus in the displaced horn being compressed like an accordion.

The backward displacement of the temporal horn in Fig. 4 corresponds exactly to a backward displacement of the point where the plexus begins. The cisternal part is stretched. Upward displacement of the anterior part of the temporal horn, and the corresponding change in the plexus, are shown in Fig. 5, a case with a large chordoma. Since the carotid siphon is stretched in an upward direction, the origin of the anterior choroidal artery is elevated, but the cisternal part is streched in a curve to reach the temporal horn. If a posterior tumour is situated basally, it elevates the posterior part of the plexus (Fig. 6a). If the lesion is situated higher up, behind the long axis of the temporal horn, it compresses the latter and makes the anterior choroidal artery accordion-shaped (Fig. 6b).

The changes seen in the lateral view of Fig. 7 indicate that the temporal horn is displaced somewhat backwards and slightly elevated. In the a. p. view it is seen that the anterior part of the plexus is displaced medially with flattening of the angle with the cisternal part. The latter is also somewhat displaced medially, and its arc is longer than usual. The anterior part of the temporal horn is displaced medially. A displacement of this type of the temporal horn is the most common in spherical

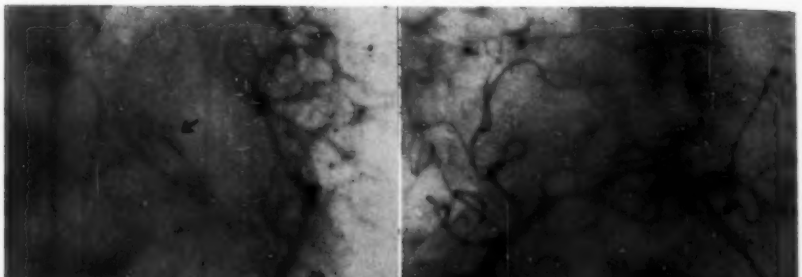


Fig. 7. Spherical meningioma from pterion. Anterior part of plexus pushed medially, and the angle between the plexal part and cisternal part flattened. In lateral view the plexal part is seen to be displaced somewhat backwards.

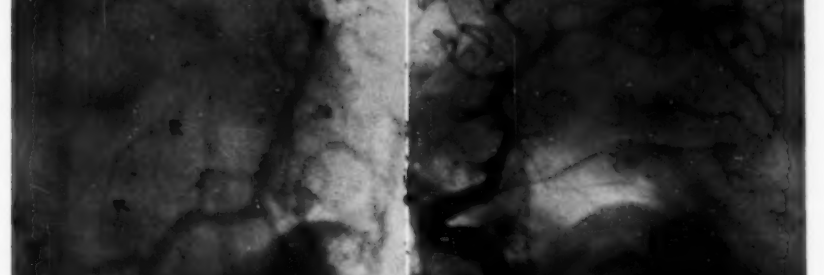


Fig. 8. Temporal glioma. Plexal part pushed backwards and medially, indicating same displacement of temporal horn. Cisternal part pushed to midline due to herniation.

meningiomas from the pterion. Gliomas, and possibly also herniations, may, however, cause similar changes in the anterior choroidal artery.

A temporal glioma (Fig. 8) with a high degree of vascular displacement

moves the plexus backwards to a marked degree, and stretches the cisternal part, which also deviates throughout its course to the midline. The plexal part is also considerably displaced medially. The tumour is deeply infiltrating, and a large temporal herniation is present. Fig. 9 shows another type of glioma which causes only slight displacement of the Sylvian vessels. The changes in the anterior choroidal artery show that the temporal horn is pushed backwards about 1 cm, this being confirmed by encephalography. The cisternal part forms a longer arc than usual; the temporal horn is not medially displaced.

Central expanding lesions stretch the anterior choroidal artery in a curve around the lesion. The dilated artery in Fig. 10 is displaced by a tumour in the thalamus. It forms markedly stretched curves both in a. p. and lateral views. In other cases the displacement in one direction — usually lateral — may predominate; this depends on the position of the tumour. Similar changes as in Fig. 10, including dilatation of the artery, were present in another case without tumour. They were caused by an old haematoma, which was removed, and 7 years later the patient is still free from symptoms. There were no signs of pathologic arteriovenous connections. In this case there is no obvious explanation for the definite widening of the artery. In several other cases the widening of the anterior choroidal artery also seems to be greater than warranted by its possible feeding of an avascular tumour. The artery is markedly stretched in all these cases. It seems that it is the protracted stretching itself that produces the dilatation, perhaps through influencing the vessel's capacity for vasoconstriction. Other arteries have also been observed to be stretched and widened. It is usually possible to observe changes in the anterior choroidal artery also in less advanced cases of central expanding lesions; this is sometimes easier than discerning changes in the temporal horn, the medial border of which is often not clearly visible. An early sign is the loss of the normal sinuosity of the artery. In Fig. 11 the artery has a peculiar step-like shape. This is due to a tumour growing up into the highly dilated temporal horn from below and elevating the choroidal plexus. The tumour is mainly intraventricular, but does not reach as far forward as to the entrance of the anterior choroidal artery, which explains the shape of the vessel. The tumour is malignant and hypervascularized, with the dilated anterior choroidal artery as feeding vessel. A similar change in the shape of the vessel has been produced in a few cases of intraventricular tumours, and this seems to be an indication that the tumour is growing partly or entirely intraventricularly. The deformation is quite different from the changes caused when the temporal horn is elevated by a basal tumour that is not intraventricular.

If the temporal horn is only deformed and not displaced, it may sometimes still be possible to observe even fairly small deformations of

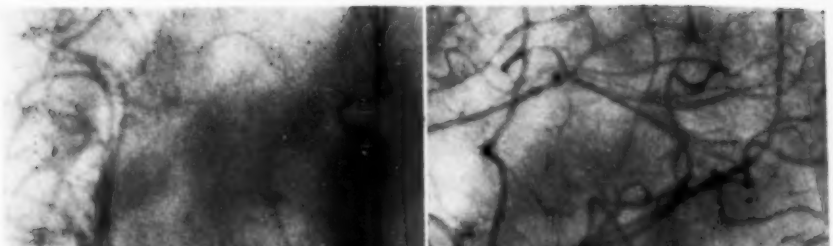


Fig. 9. Temporal glioma without marked vascular displacement. Plexal part pushed 1 cm backwards. Cisternal part forms a longer curve than normal, indicating anterior downherniation.

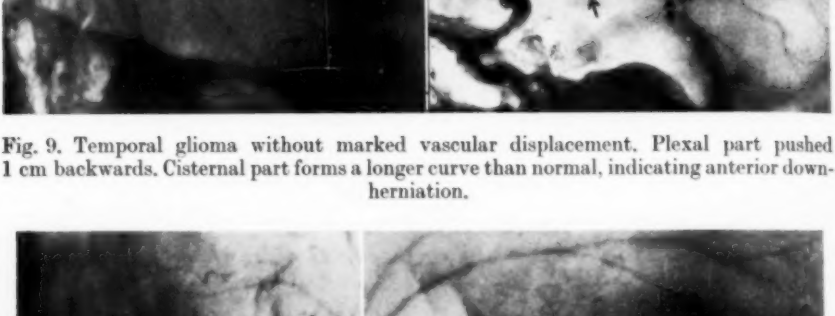


Fig. 10. Tumour in thalamus. Anterior choroidal artery is dilated and describes a considerably stretched arch both in a. p. and lateral views.

the plexus. The local indentation in the posterior part of the horn by a laterally situated temporal glioma, shown in Fig. 12, gives the same deformity to the choroidal plexus. A depression of the anterior part of the temporal horn with flattening of the knee is a common deformation; this may also be caused by remotely situated tumours. In cases in which

the hippocampus really is compressed basally it is possible to observe that the 'plexus point' is situated at a lower level than normal and that the cisternal part has a corresponding course, more straight backwards (Fig. 13). Small changes, however, are difficult to judge. If the temporal horn is dilated, the plexus lies at the bottom of the supracornual cleft, and atrophies may produce a similar picture as a depression of the temporal horn.

The investigation shows that different kinds of displacements of the temporal horn, and sometimes large deformations, produce corresponding changes in the plexal part of the anterior choroidal artery. In such cases, the cisternal part is often secondarily affected either so that the distance between the carotid artery and the temporal horn has been changed, or its direction altered, by the displacement of the horn. When the plexus lies in the supracornual cleft, information is obtained only about this cleft, and the medial border of the temporal horn, but not about the lateral cleft, nor about any possible flattening of the temporal horn. Such a deformation is common and diagnostically important both in tumours close to the horn and those lying more distant. Pneumography is, of course, required for a close evaluation of the temporal horn but the changes in the anterior choroidal artery shown by carotid angiography afford some information about its position which cannot otherwise be obtained by this method; it may often prove of diagnostic value.

The cases in which the temporal horn showed no marked change have been placed in one group. In this group there were no alterations in the plexal part, but in some cases the cisternal part was affected. Space-occupying lesions, growing in the intercrural cistern betwen the two unci, large enough to flatten them medially, *e. g.* large suprasellar tumours and subfrontal tumours in the midline growing backwards, change the course of the cisternal part. In an a. p. view, the cisternal part may be flattened from the medial side, the normal arc around the uncus having disappeared; it runs straight backwards. A similar change occurred in 2 cases of small clinoidal meningeomas, and in 1 case due to an anterior tentorial herniation on the opposite side, large enough to flatten the contralateral uncus. If a frontal tumour has a more lateral position, it displaces the carotid siphon backwards. The cisternal part then retains its normal main direction, but is perhaps too long and therefore tortuous or kinked. If the tumour is situated still further laterally, it may flatten the temporal horn (either directly or by means of a down-herniation overhanging the sphenoidal ridge). Then, such changes as demonstrated in Fig. 13 may arise. Our material is not large enough to permit us to conclude whether these changes are sufficiently constant to be of any practical help in determining how far laterally a frontal tumour is situated.

The most common cause for direct pressure on the cisternal part is,

Fig. 11. Step-like deformation of anterior choroidal artery, due to mainly intraventricular glioma, growing upwards into temporal horn. The malignant tumour has the anterior choroidal artery as its feeding vessel.

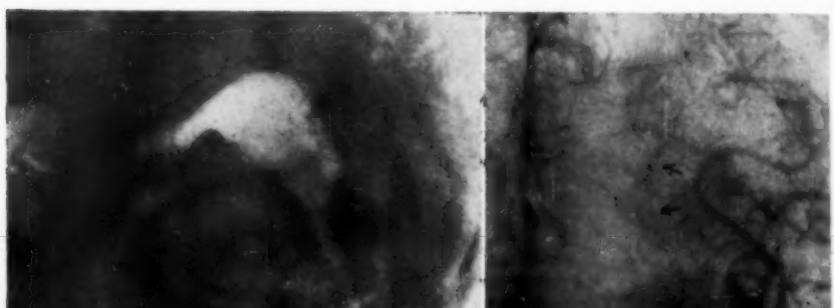


Fig. 12. Laterally situated glioma producing local indentation in posterior part of temporal horn. Choroidal plexus shows corresponding deformity.

however, an anterior tentorial down-herniation. Angiographic changes in tentorial herniations are discussed in a separate paper in this issue (p. 233), to which reference to additional illustrations is made. The positions of the cisternal part on the medial surface of the uncus makes it easily affected if the hippocampal convolution is displaced medially (Fig. 8). Large herniations produce obvious displacement of the artery

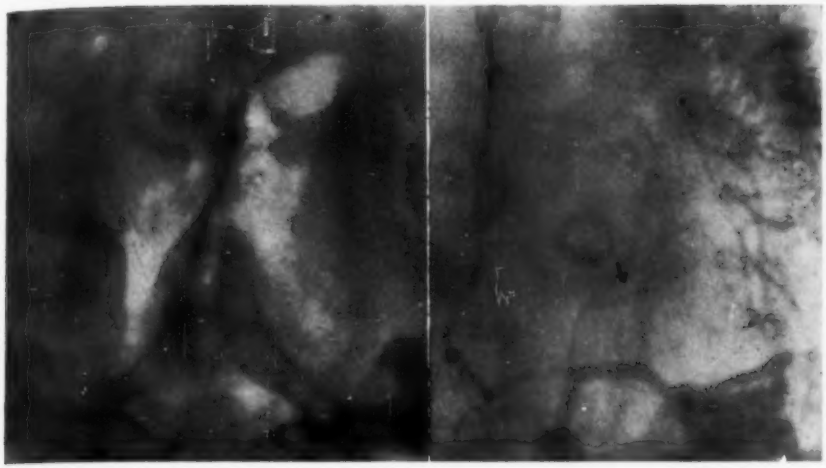


Fig. 13. Subfrontal medial tumour growing backwards into chiasmatic and intercrural cisterns. Uncus flattened from medial side; the cisternal part has therefore lost its convexity in a medial direction and runs directly backwards.

medially, and it may even describe a curve crossing over to the opposite side of the midline. In most cases, however, the changes are so small that it may be difficult to determine if the arc around the uncus is displaced medially (Fig. 9). As a rule, an opportunity for comparison with the other side is, naturally, lacking. When the anterior part of the hippocampal gyrus is displaced medially and, so to speak, rolls over the edge of the tentorium, the anterior choroidal artery must circumvent not only the uncus, but also the herniated parts of the hippocampus (see Fig. 7, p. 236). The consequence is that in a. p. views the cisternal part describes a much longer curve than normal. This change is often more obvious than the medial displacement. The beam direction as well as the ang'e between the object and the film naturally affects the length of the arc appearing in the film. By using a known, consistent technique and by comparison with the lateral view one should therefore determine which beam direction has been used for exposure of the a. p. view, in order to decide whether the cisternal part describes a longer arc than normal; if this is the case, an anterior down-herniation is present (Fig. 9). The divergence from the normal is, however, often obvious; in lateral views the vessel appears stretched and sometimes slightly depressed. Changes in the anterior choroidal artery constitute one of the most common and definite indications of anterior down-herniations in carotid angiography.

SUMMARY

Description of topography and normal roentgenologic anatomy of the anterior choroidal artery, based on a material of 30 specimens and 100 normal angiographies and comparison between pneumography and angiography. Displacements and more considerable deformations of the temporal horn caused corresponding changes in the 'plexal part' of the anterior choroidal artery, most often accompanied by secondary changes in its 'cisternal part'. This made it possible to draw certain conclusions about the position of the temporal horn in angiography. In cases without changes in the temporal horn the plexal part was not affected. The cisternal part was changed by expanding processes flattening the medial surface of the uncus, and by anterior down-herniations.

For studying the anterior choroidal artery, rapid serial angiography is the superior method.

RÉSUMÉ

Description de la topographie et de l'anatomie radiologique normale de l'artère choroïdienne antérieure, basée sur un matériel de 30 pièces anatomiques et de 100 angiographies normales, et comparaison entre la pneumographie et l'angiographie. Les déplacements et les déformations plus importantes de la corne temporale donnent lieu à des modifications correspondantes de la «partie plexuelle» de l'artère choroïdienne antérieure, le plus souvent accompagnées de modifications secondaires dans sa «partie cisternale». Ceci a permis de tirer certaines conclusions sur la position de la corne temporale sur l'angiographie. Dans les cas où il n'existait pas de modifications de la corne temporale, la partie plexuelle n'était pas affectée. La partie cisternale était modifiée par les tumeurs qui aplatissent la face interne de l'uncus et par les herniations antéro-inférieures.

Pour l'étude de l'artère choroïdienne antérieure, la sérioangiographie rapide est la méthode de choix.

ZUSAMMENFASSUNG

Der Verfasser beschreibt die Topographie und die normale Röntgenanatomie der Arteria choroidalis anterior. Er stützt sich dabei auf ein Material von 30 Präparaten und 100 normalen Angiographien sowie auf Vergleiche zwischen Pneumographien und Angiographien. Verschiebungen und grössere Deformierungen des Temporalhornes erzeugten entsprechende Veränderungen im »Plexusabschnitt« der Arteria chorioidea anterior, welche sehr häufig von sekundären Veränderungen in ihrem »zysternalen Abschnitt« begleitet sind. Hierdurch wurde es möglich, gewisse Schlussfolgerungen über die Lage des Temporalhornes bei der Angiographie zu ziehen. In Fällen ohne Veränderungen des Temporalhornes war der Plexusabschnitt nicht angegriffen. Der zysternale Abschnitt wurde durch expansive Prozesse verändert, welche die mediale Oberfläche des Uncus abplatteten, oder durch vorn-unten gelegene Massenverschiebungen.

Für das Studium der Arteria chorioidea anterior ist die schnelle Serienangiographie die überlegene Methode.

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ANGIOGRAPHY AND PNEUMOGRAPHY IN THE DIAGNOSIS OF SLIGHTLY SPACE-OCCUPYING SUPRATENTORIAL TUMOURS

by

I. Wickbom

Ever since cerebral angiography came into more general use discussions have arisen as to whether or not it is superior to pneumography in the diagnosis and localization of intracranial expanding lesions. In most cases, no doubt, a brain tumour large enough to cause clinical signs may be diagnosed and localized fairly well with either method. As shown in earlier publications (1946 and 1948) there are cases, however, in which the lesion can be clearly demonstrated only by means of one method while the other produces more or less normal appearances. Neuroradiology is rapidly developing, however, and the technique of angiography is improving. Apparatus for rapid serial examinations has become available and more experience has been gained in interpretation. Thus, more attention is nowadays paid to the appearances of the central veins as well as the superficial small vessels which greatly contribute in forming what may be called 'the vascular pattern' of the brain. The technique of encephalography has likewise been improved. Using the technique described by LINDGREN at the symposium in Rotterdam, it is possible, at least to some extent, to direct the gas to various parts of the brain surface, thus also permitting a more systematic examination of the sulci. Later on a case will be described in which a change in the appearances of the sulci was the only abnormality seen at pneumography (Case 9).

I have been interested to see whether our earlier experiences still hold after these improvements in technique and interpretation. I have therefore investigated proved brain tumours examined in Röntgen Department III of Sahlgrenska Sjukhuset during the last four years.

In order to form an opinion regarding the reliability of the two methods, and their comparable value, the material of supratentorial tumours has been divided into the following four groups. (Other expanding processes such as vascular and inflammatory lesions have been excluded from the material.) Only proved cases are included, with the exception of those cases in which operation was considered useless because of typical glioblastoma vessels, seen in the angiogram, or of central extension evident in the air-study.

1) Cases in which only angiography was performed.

2) Cases in which only pneumography was used and angiography was not considered necessary for further details.

3) Cases in which each method allowed a fairly accurate localization but the other was used as well, in order to gain more information concerning the extension and true nature of the lesion.

4) Cases in which one of the methods was interpreted as normal or anyway failed to permit a definite diagnosis. In most of these, the lesion could be diagnosed with the other method, or after combining the results of both methods. In 3 cases, however, both of them failed on the first occasion. In 2, the examinations were repeated some time later (in 1 case only a month, and in 1 case more than a year later) when definite changes were seen.

Group 1) (only angiography) consists of 71 cases, mainly of highly vascular tumours such as meningiomas, glioblastomas, and secondary deposits.

Group 2) consists of only 16 cases, most of them of adenomas of the hypophysis with suprasellar extension and a few tumours invading the thalamus.

Group 3) includes 54 cases in most of which pneumography was performed as the first examination because no clinical signs indicating the side of the lesion were present. In some cases the air-study was incomplete inasmuch as only the contralateral ventricle was filled. Angiography was performed in order to obtain a better idea of the exact degree of extension and the true nature of the lesion. In those cases in which angiography was used as the first method, the air-study was performed mainly to gather more information concerning the central extension of the lesion, or to find out if it was intra- or extra-cerebral.

Group 4) will be discussed more in detail. It includes 30 cases; 5 were of suprasellar or central tumours, such as adenomas of the hypophysis, pinealomas, and tumours growing in the thalamus where only insignificant changes were seen at angiography. One case represented an unusual type of angioma growing in the corpus callosum; the angiographic appearances were peculiar. The ventricular system was somewhat dilated but otherwise roughly within normal limits. There were

2 cases of meningiomas mainly growing in the bone, in 1 around the orbital fissure and in the other parasagittaly; each had only a small intracranial extension. The meningioma in the first was highly vascular, as seen by angiography, and displaced the siphon slightly but had no influence on the ventricular system. The growth in the other caused only slight changes in the vessels and the corresponding lateral ventricle. There was 1 case of a 'carpet-growing' meningioma of the sphenoidal wing (meningeom en plaque).

In the remaining 21 cases there were true hemisphere tumours. In 7 (4 gliomas, 2 meningiomas, and 1 multiple metastasis), no, or only insignificant changes were seen at angiography, and the condition could be diagnosed with certainty only by means of pneumography. Three of the growths were mainly deeply situated, close to the ventricular system, the others were at least partly superficial. Two were frontal tumours, 4 parietal, and 1 a posterior temporal tumour.

Case 1 (Figs. 1 and 2). M. A., female, aged 70, with attacks of giddiness for 10 years. A small defect was found in the visual field indicating a lesion in the right occipital lobe. The reflexes were slightly more lively on the left side than on the right. Roentgen examination of skull revealed local sclerosis in the right occipital area. *Angiography* (right int. carotid artery): Only small and insignificant changes could be seen in the form of a slight stretching of the vessels in the occipital lobe. *Encephalography:* There was a marked displacement forwards and basally of the posterior part of the right ventricle corresponding to the local sclerosis in the bone. The diagnosis of a meningioma was confirmed at operation.

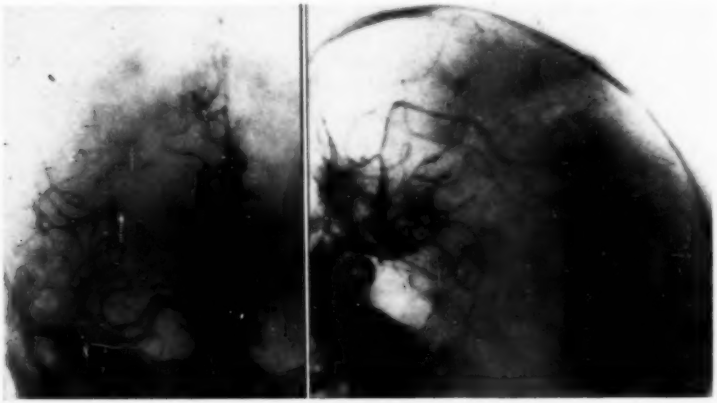


Fig. 1. Case 1 (Right occipital meningioma). Angiography of right carotid artery. Vessels in occipital lobe run a slightly stretched course. Otherwise no abnormality.

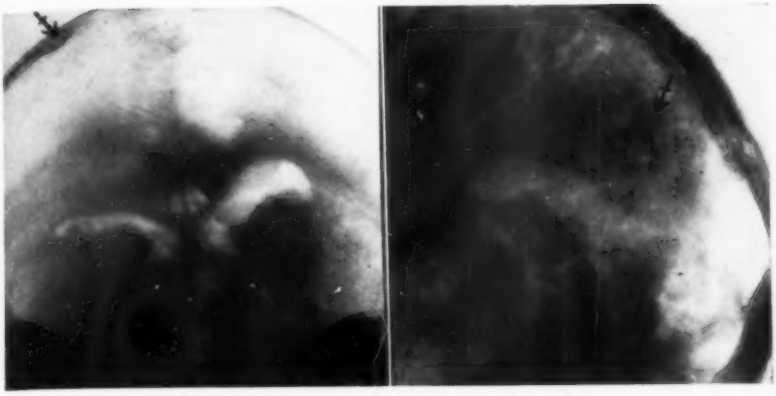
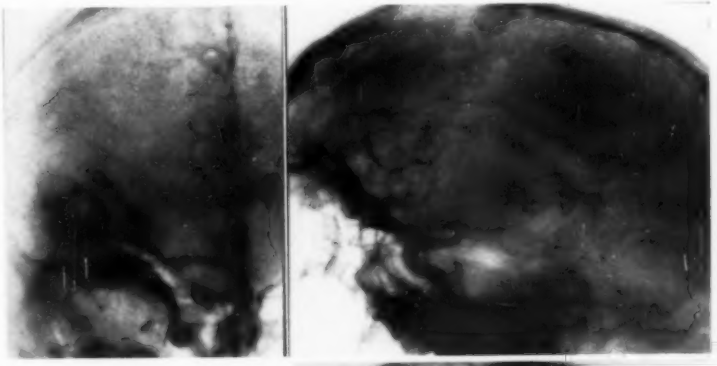


Fig. 2. Encephalography of same case as in fig. 1.
Marked displacement forwards of posterior part of right ventricle, corresponding to local sclerosis of the bone (arrow).



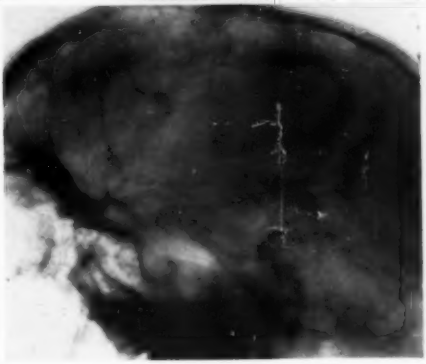


Fig. 3. Case 2.
Parasagittal meningioma in right parietal area. Angiography of right internal carotid artery.

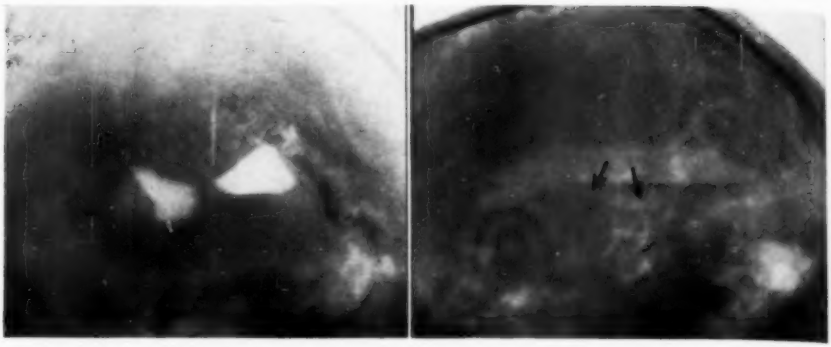


Fig. 4. Case 2. Encephalography. Roof of right lateral ventricle depressed, indicating parietal parasagittal lesion (arrows). Air-filled arch-formed sulci surrounding tumour area. Subdural air on right side lies in front of tumour.

Case 2 (Figs. 3 and 4). G. P., male, aged 55. Attack of headache followed by slight paresis of left arm and leg 3 months before admission. Neurologic examination: No abnormality apart from slightly impaired superficial sensation in the left arm and leg. *Angiography:* No definite changes. On *encephalography*, however, displacement of the right ventricle suggested a parietal parasagittal tumour. *Operation:* A meningioma the size of a golf-ball was removed from the right parietal region.

Case 3 (Figs. 5 and 6). I. L., female, aged 32, with a 2-year history of attacks of 'petit mal'. Shortly before admission she had also had an attack of 'grand mal' with generalized seizures. Neurologic examination: Normal. *Angiography*, both of the carotid and the vertebral arteries, failed to show any definite abnormalities. *Encephalography:* The posterior part of the left temporal horn was shown to be displaced upwards, and the trigone was deformed by an indentation from below and laterally. *Operation:* An astrocytoma was found tempero-parietally and close to the ventricle.

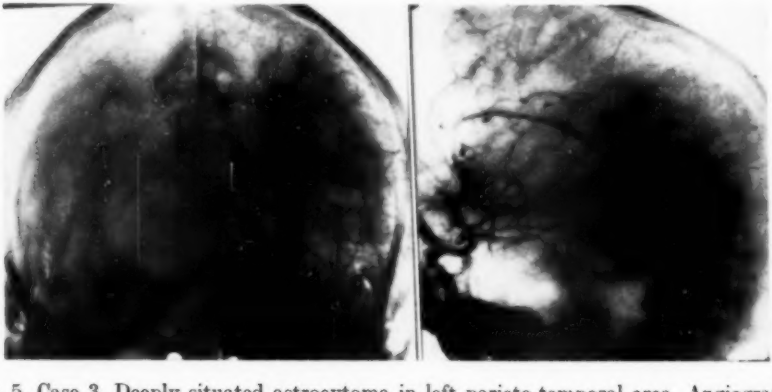


Fig. 5. Case 3. Deeply situated astrocytoma in left parieto-temporal area. Angiography of left carotid artery.

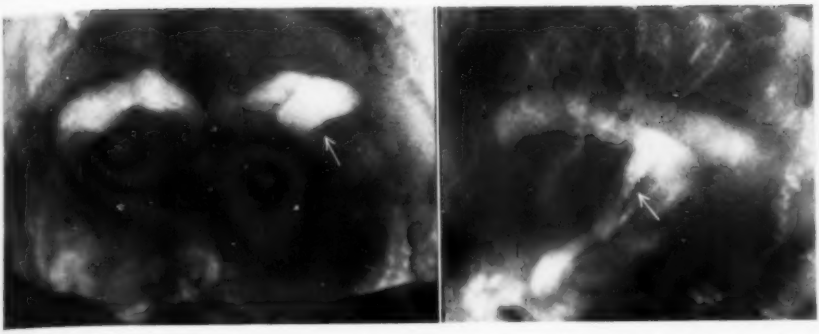


Fig. 6. Same case as in fig. 5. Posterior part of temporal horn elevated and trigone deformed.

Case 4 (Figs. 7 and 8). G. T., female, aged 54, with a 3-months history of attacks of numbness in the left arm. She was unconscious on one occasion for a few minutes following such an attack. Neurologic examination: Normal. *Angiography:* Slight displacement of the anterior cerebral artery to the left; no other abnormality noted. On *encephalography*, on the other hand, could a definite diagnosis of an intracerebral lesion in the basal part of the right frontal lobe be made. *Operation:* The tumour proved to be an astrocytoma; it could not be radically removed.

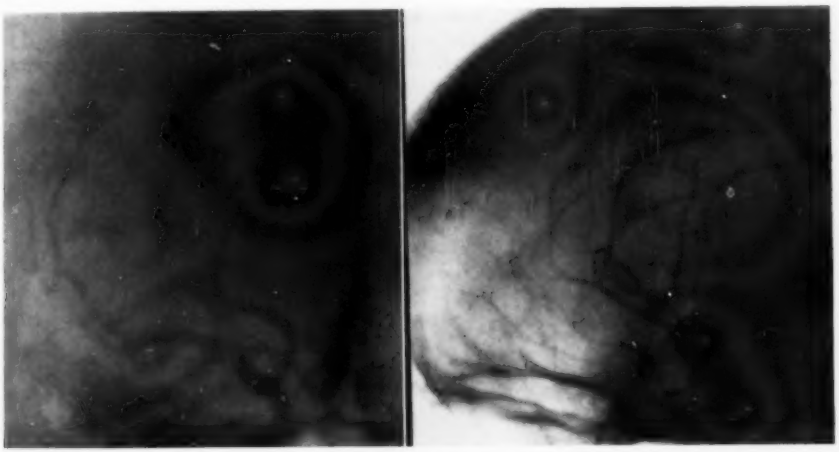


Fig. 7. Case 4. Astrocytoma in right subfrontal area. Angiography of carotid artery. Slight displacement of anterior part of anterior cerebral artery with suggestion of stretched vessels in frontal lobe; changes too small to be diagnostic, however.

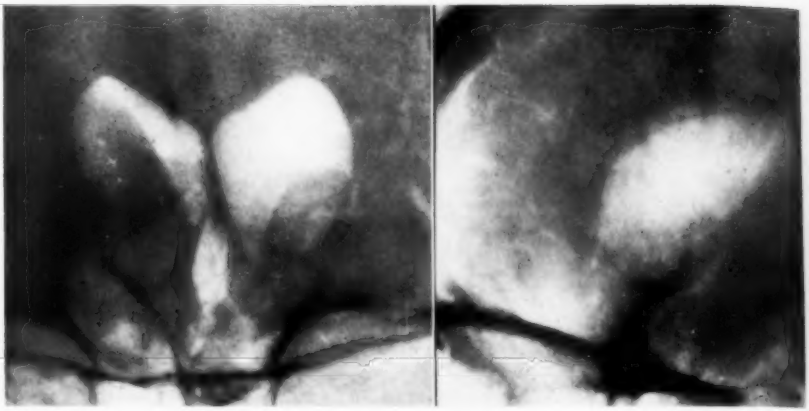


Fig. 8. Case 4. Encephalography. Anterior part of ventricular system, especially basally, displaced to left. Right anterior horn flattened from outside and below.

In 5 cases (2 meningiomas and 3 astrocytomas) a definite diagnosis was obtained on angiography whereas pneumography appeared more or less normal. In 4 of them, a frontal, and in one, a parietal tumour was present.

Case 5 (Figs. 9 and 10). I. S., male, aged 33, had for 2 years had attacks of right-sided Jacksonian epilepsy of increased frequency. There was an EEG-focus on the left side but neurologic examination revealed no abnormalities. *Encephalography:* The ventricular system appeared essentially normal. *Angiography:* There was no displacement of the arteries. In a film taken in the venous phase, however, the vessels in the parietal region

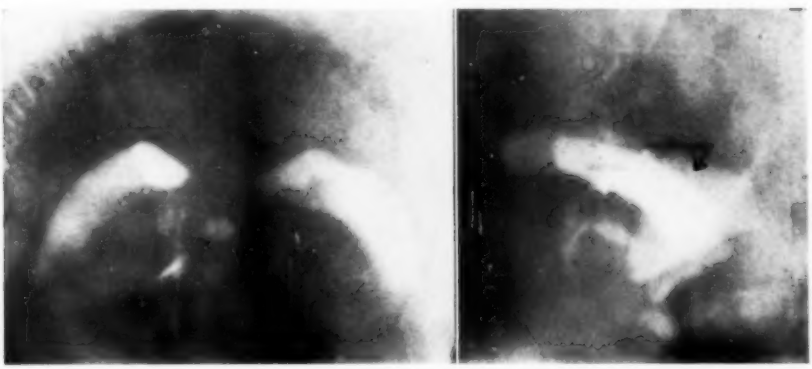


Fig. 9. Case 5. Astrocytoma in left parietal lobe. Slight downward displacement of trigone and, basally, of posterior part of body.

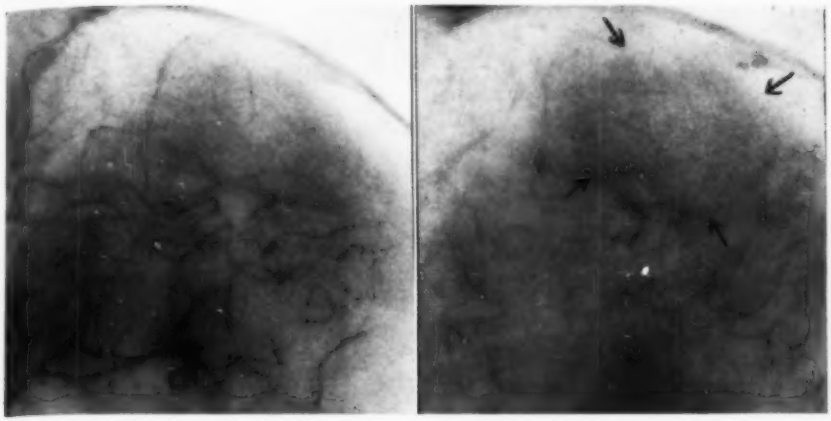


Fig. 10. Same case as in fig. 9. Angiography of left carotid artery. In venous phase, ringformed arrangement of vessels around tumour (arrows); otherwise no definite abnormality.

had an arch-formed arrangement around an area the size of a golf-ball. This proved at operation to be an astrocytoma, which was superficially well defined but deeper down had a more infiltrating manner of growing.

Case 7 (Figs. 11 and 12). A.' H., female, aged 69. Epilepsy for about 2 years, first in the form of occasional attacks of 'grand mal' and later lesser attacks of Jack-

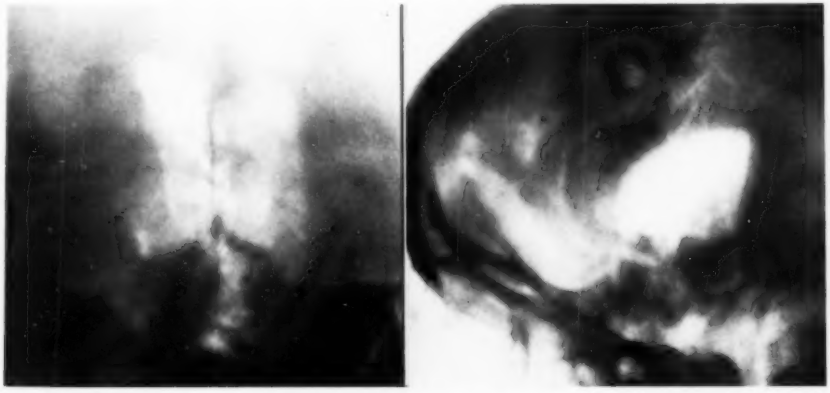


Fig. 11. Case 7. Meningioma in right frontal pole; slight flattening of anterior border of right ventricle.

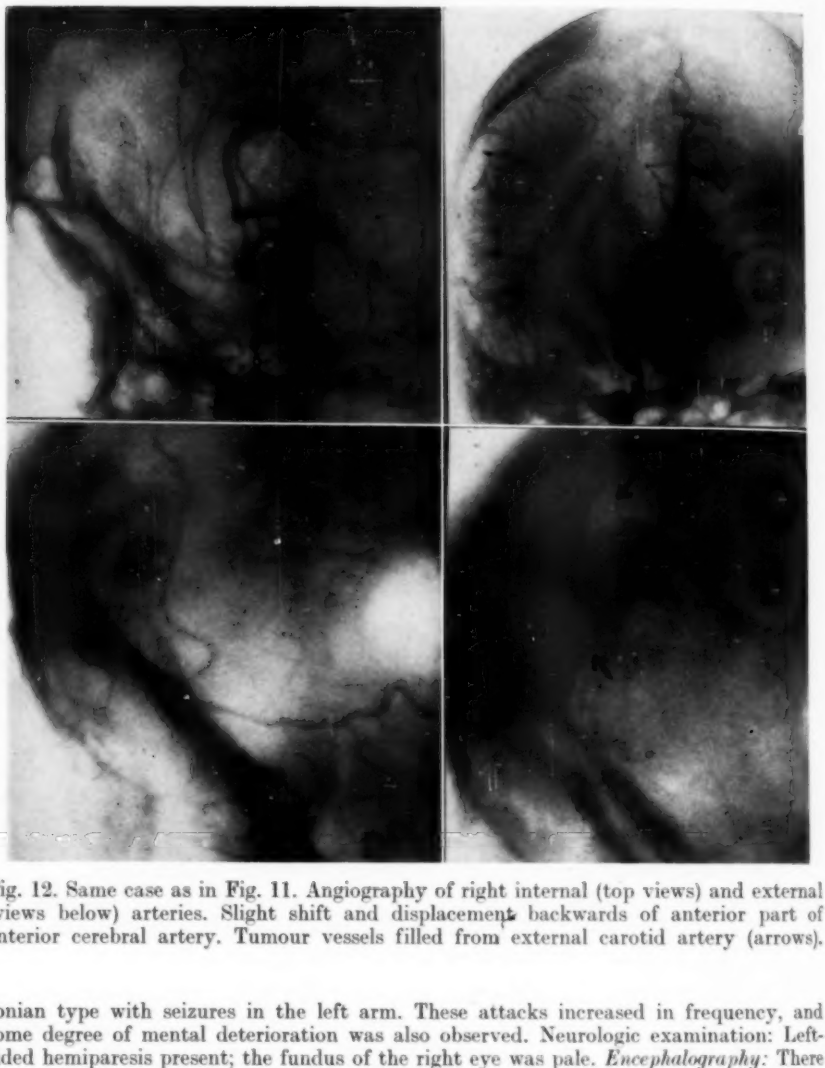


Fig. 12. Same case as in Fig. 11. Angiography of right internal (top views) and external (views below) arteries. Slight shift and displacement backwards of anterior part of anterior cerebral artery. Tumour vessels filled from external carotid artery (arrows).

sonian type with seizures in the left arm. These attacks increased in frequency, and some degree of mental deterioration was also observed. Neurologic examination: Left-sided hemiparesis present; the fundus of the right eye was pale. *Encephalography:* There was slight flattening of the right anterior horn, the anterior border of which lay 1 to 2 mm further back than the corresponding part of the left anterior horn. *Angiography* (right int. carotid artery): Essentially normal, apart from slight displacement of the anterior cerebral artery. *Angiography* (right ext. carotid artery), however, revealed a highly vascular meningioma in the right frontal pole. Confirmed at operation.

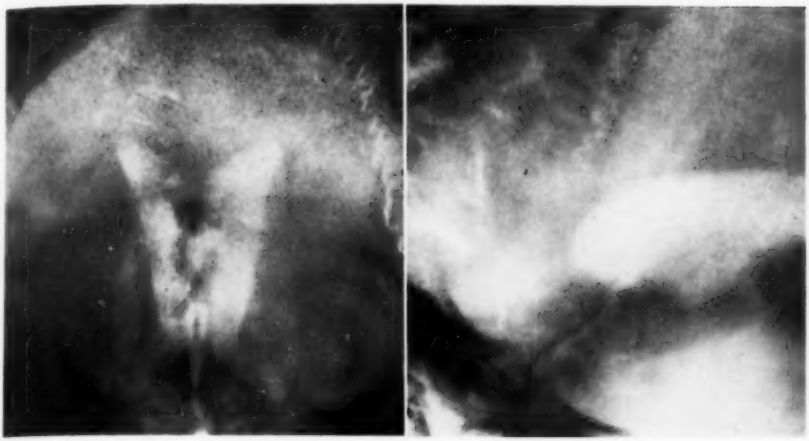
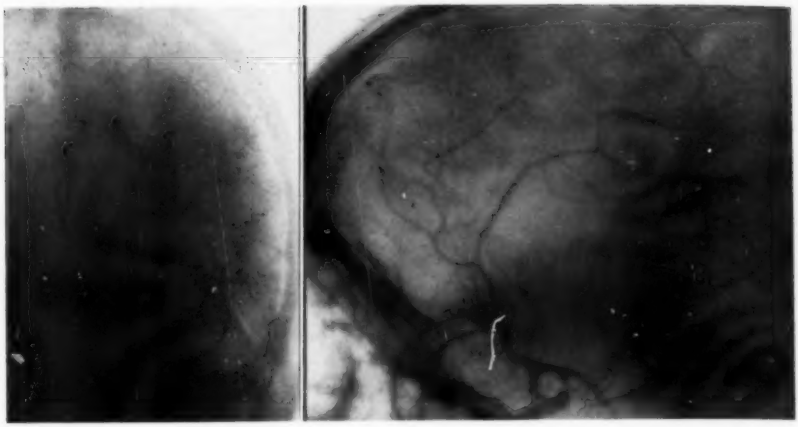


Fig. 13. Case 8. Glioma in left frontal lobe. Encephalograpy normal.

Case 8 (Figs. 13 and 14). A. B., male, aged 51, with epileptic fits of Jacksonian type with seizures in the right arm and aphasia of one year's duration, and also some degree of mental deterioration. Neurologic examination: Slight atrophy of the muscles of the right shoulder. *Encephalography:* No abnormalities of the ventricular system or sulci. *Angiography:* There was a suggestion of displacement of the anterior cerebral artery; in the frontal lobe the vessels ran a stretched and somewhat irregular course. The changes were small but considered sufficient to warrant a diagnosis of infiltrating tumour. *Operation:* No definite changes could be seen macroscopically but the frontal lobe was resected at the level of the sphenoidal ridge; microscopic examination of the removed part revealed an astrocytoma.

In 6 cases (5 gliomas and 1 meningioma) small changes were found both at angiography and pneumography, but they were such that definite conclusions could not be drawn. Since both examinations indicated a lesion in the same area and thus were corroborative, the diagnosis could be made with more certainty. In one case the diagnosis was further supported by the demonstration of calcifications of the type found in oligodendrogliomas.

Case 9 (Figs. 15 and 16). A. A., female, aged 39, had during the previous year had five attacks of general epileptic convulsions and several small attacks without loss of consciousness but followed by aphasia. Neurologic examination: Right-sided hemiphlegia present. *Encephalography:* The ventricular system appeared normal; the sulci of the left frontal lobe had, however, a peculiar arch-formed arrangement. *Angiography* (right int. carotid artery): There was a suggestion of displacement of the arteries in the median fissure. The vessels in the frontal lobe ran a slightly stretched course.



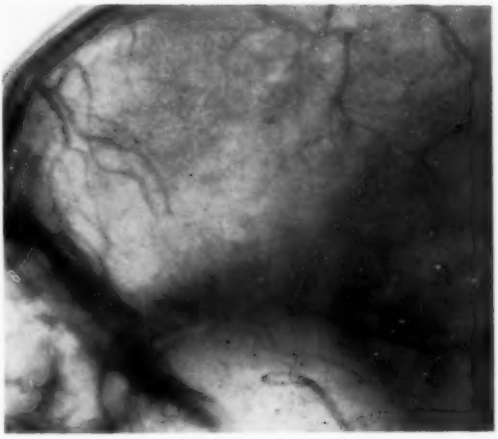


Fig. 14. Same case as in fig. 13.

Angiography of left int. carotid artery. Slight but definite displacement of anterior cerebral artery. Vessels in frontal area appear stretched. These changes although small were considered to be diagnostic of an infiltrating tumour.

Thus, only small and not entirely significant changes were found in both examinations but as they indicated a lesion in the left frontal lobe a diagnosis of astrocytoma was made. *Operation:* The convolutions in the area were found to be broad, hard and pale. No attempt was made to remove the tumour and no biopsy performed. The patient died a few days later. *Autopsy:* Infiltrating astrocytoma reaching far back and located mainly in the subcortical layer.

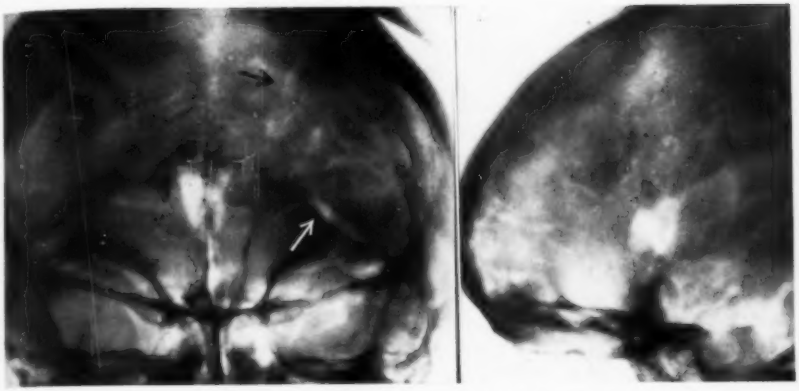


Fig. 15. Case 9. Encephalography. Ventricles small but appear normal. Air-filled sulci on left side have arch-formed arrangement. These changes in combination with the small angiographic abnormalities were considered diagnostic of infiltrating lesion in left frontal lobe.

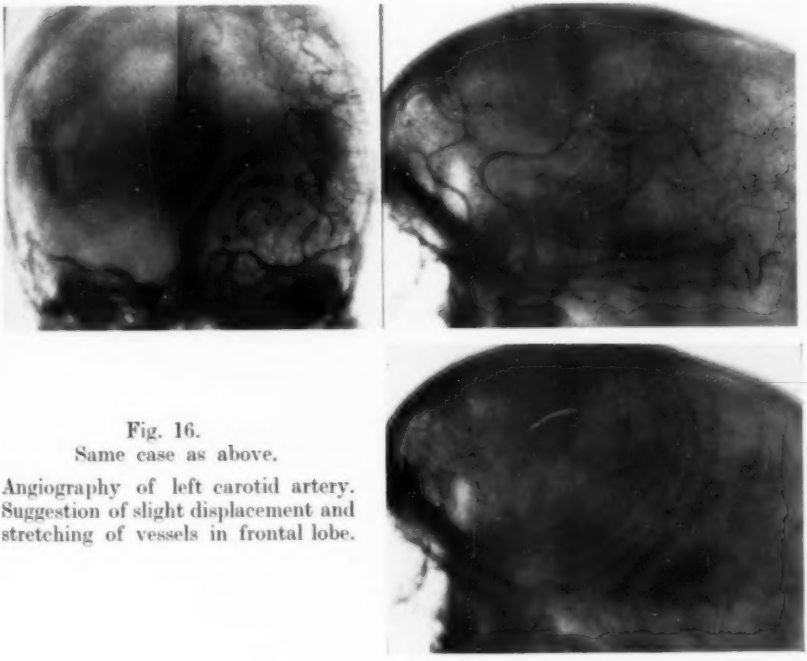


Fig. 16.
Same case as above.

Angiography of left carotid artery. Suggestion of slight displacement and stretching of vessels in frontal lobe.

Conclusions

In spite of improved techniques there are still cases in which the correct diagnosis of a brain tumour cannot be made with only one of the two methods we have at our disposal (pneumography and angiography). As a rule, the tumour may be diagnosed and localized if a subsequent examination is made with the other alternative method, or if the results of the two examinations are combined. It is true that in the views presented in this paper, small changes may be observed in some of the cases that have been recorded as essentially normal, but these changes are in my opinion too small to be regarded as definitely abnormal. Most of these tumours are of the infiltrating type, but so can meningiomas be. In the majority of the cases presented, the clinical signs are insignificant and afford only slight evidence of the presence of tumour.

SUMMARY

In 30 out of 171 consecutive cases of supratentorial brain tumours, during the last four years, no changes or only insignificant ones could be found by means of either pneumography or angiography alone. When the examination was supplemented with the alternative method, a definite diagnosis was obtained. It appears that the possibility of a brain tumour cannot be ruled out with certainty by means of one only of the two methods, since in exceptional cases either method may give normal appearance at the first examination.

RÉSUMÉ

Dans 30 cas sur 171 cas consécutifs de tumeurs cérébrales sus-tentorielles, dans les quatre dernières années, la pneumographie ou l'angiographie employées isolément n'ont permis de déceler aucune modification, ou seulement des modifications insignifiantes; complétées l'une par l'autre, elles ont donné un diagnostic précis. Il en résulte que l'emploi d'une seule méthode ne permet pas d'éliminer avec certitude la possibilité d'une tumeur cérébrale, étant donné que, dans des cas exceptionnels, l'une ou l'autre méthode peut donner, au premier examen, une image normale.

ZUSAMMENFASSUNG

In 30 von 171 konsekutiven Fällen mit supratentoriellen Hirntumoren konnten während der letzten 4 Jahre bei ausschliesslicher Benutzung der Pneumographie oder der Angiographie keine oder nur nicht signifikative Veränderungen gefunden werden. Nach Ergänzung der Untersuchung mit der alternativen Methode konnte die endgültige Diagnose gestellt werden. Es scheint, dass das Vorhandensein eines Hirntumors mit Hilfe nur einer der Methoden nicht mit Sicherheit festgestellt werden kann, da in Ausnahmefällen beide Methoden bei der ersten Untersuchung ein normales Bild geben können.

FROM THE ROENTGEN DEPARTMENT (DIRECTOR: PROF. ERIK LINDGREN), SERAFIMERLASARETTET, STOCKHOLM, SWEDEN

RADIOLOGIC DIAGNOSIS OF INTRAVENTRICULAR MENINGEOMAS

by

Bengt Falk

The title of this paper is not entirely adequate. It should read 'Meningeomas within the lateral ventricles', since only this type of tumour will be dealt with. Such meningeomas are comparatively rare, but some 60 cases have been described in the literature, most papers being concerned with the possibility of a clinical diagnosis. CUSHING and EISENHARDT in 1938 tried to formulate a syndrome characteristic of these tumours, but increased experience has shown that this attempt is not particularly helpful in practical work. Most authors are probably now agreed that a purely clinical diagnosis of these growths is hardly possible. The best and most exhaustive paper on the subject is, as far as I have been able to find, the one published by WALL in 1954, in which the author writes: "Many gliomas fulfill Cushing's conditions." It is therefore important that the radiologic diagnosis of these tumours is as certain as possible. Due to the deep location of intraventricular tumours, there seems to be a very great risk that one may consider the tumour to be growing centrally inwards and thus be inoperable. Judging by the literature, the benign nature and intraventricular position of the tumour are often surprise findings.

WALL's material consists of 8 such meningeomas, and he also deals with their roentgenologic diagnosis. More recently, HUANG and ARAKI have published an article, describing 5 cases of meningeomas in the lateral ventricles, and in which they also discuss the arteriographic diagnosis. We have, during the past 10 years, observed 9 cases of meningeomas in the lateral ventricles, and it therefore seems suitable to compare our experiences with those of WALL and the Japanese authors in so far as they concern the roentgen diagnosis.

The changes which may be observed in conventional films are signs of increased intracranial pressure or calcifications. In our material, 6

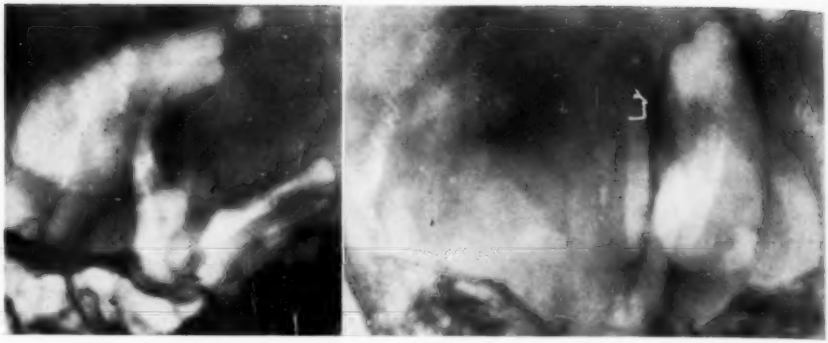


Fig. 1. Air surrounds greater part of meningeoma in temporal horn.

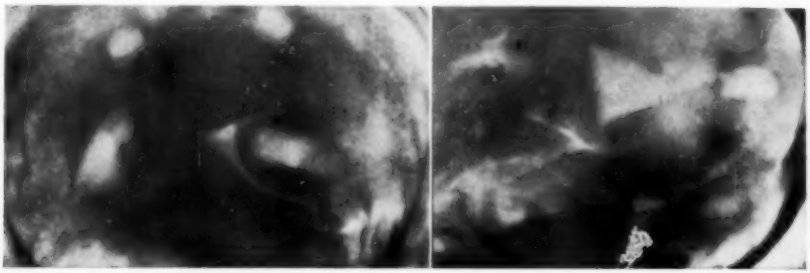


Fig. 2. Meningeoma, surrounded by air, in the trigone and posterior part of body of lateral ventricle. No general dilatation and practically no displacement of ventricular system.

cases had increased intracranial pressure, and, judging by the literature also, pressure changes in the sella region seem to be relatively common. CUSHING and EISENHARDT stated in 1938 that meningeomas lacking contact with the dura tend to contain calcifications more than other meningeomas. Out of WALL's 8 cases, one contained calcifications, as did 3 of our 9 cases. This seems to confirm the observation by CUSHING and EISENHARDT, since calcifications in meningeomas are rather uncommon. The changes just mentioned are, however, as a rule of value only in that they indicate the existence of an intracranial expanding lesion. They give no information about its intraventricular location. The type of calcification may give a hint, however, of the nature of the process. In our 3 cases the calcifications were nodular. In one of them there was also a linear calcification, somewhat like a capsule calcification, or the type of calcification that may appear in aneurysms.

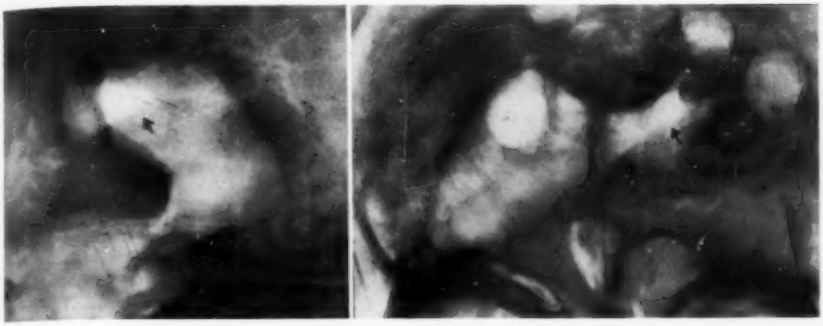


Fig. 3. Large meningeoma, completely filling posterior part of body of lateral ventricle and compressing third ventricle from above. Very slight displacement of ventricular system.

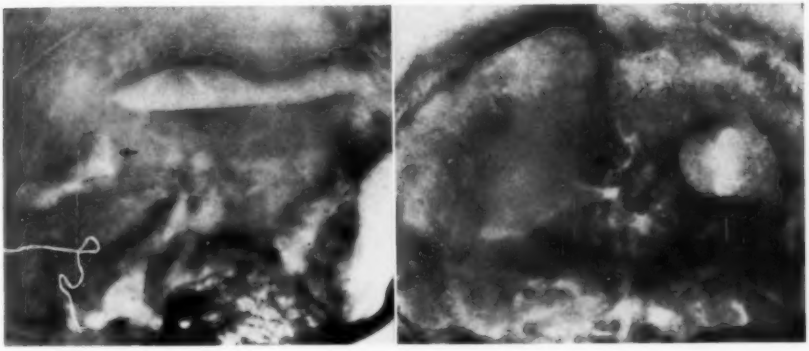


Fig. 4. Glioma, also obstructing lateral ventricle, but producing marked lateral displacement of ventricular system.

In most of the cases described in the literature, pneumography — usually ventriculography — demonstrated the presence of an intraventricular tumour. In the 7 cases we have examined with pneumography, an intraventricular growth or extension could be demonstrated in all the cases. Yet, it is in pneumography often difficult to decide whether there is a true intraventricular tumour, or if a mass originating from the parenchyma of the brain has grown into and fills some part of the ventricular system. A tumour whose greater part is situated outside the ventricular system generally causes a larger displacement of the ventricles than one which is exclusively intraventricular, but there are exceptions. Thus, on the one hand, many infiltrating gliomas cause

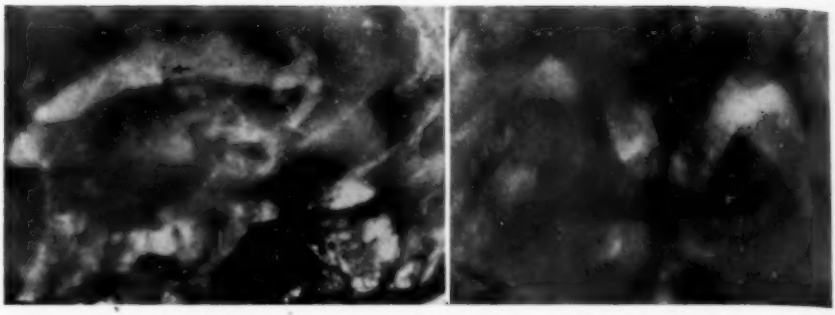


Fig. 5. Intraventricular meningeoma mainly in trigone. Only slight displacement.

very small displacements of the ventricular system and, on the other hand, certain intraventricular meningeomas may cause a relatively marked lateral displacement.

Two cases with tumour situated in the trigone showed no lateral displacement at all. In the other cases, with tumour situated in the temporal horn, trigone, or body of the lateral ventricle, there were only slight displacements. Thus, our experience differs from WALL's, who states that "there is usually considerable displacement of the lateral and third ventricles to the opposite side". Intraventricular meningeomas cause a local dilatation of that part of the ventricular system in which they are located, but do not as a rule cause a general dilatation of the ventricular system. The tumour may, however, be so situated or of such a size that it compresses part of the lateral ventricle, resulting in a possible dilatation of other parts. In one case in our material, the tumour stretched so far forward that the foramen of Monroe was compressed, causing a dilatation of the lateral ventricle of the same side. In another case, with a tumour in the trigone, the posterior part of the third ventricle was considerably displaced and compressed, causing a moderate general dilatation.

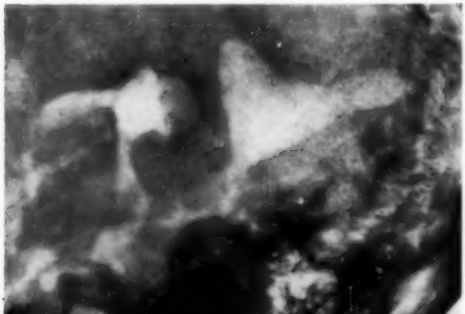


Fig. 6. Glioma in the occipital lobe displacing occipital horn and trigone anteriorly. Only part of tumour is growing inside ventricle.

Figs. 1 and 2 demonstrate cases in which the intraventricular nature of the tumours are

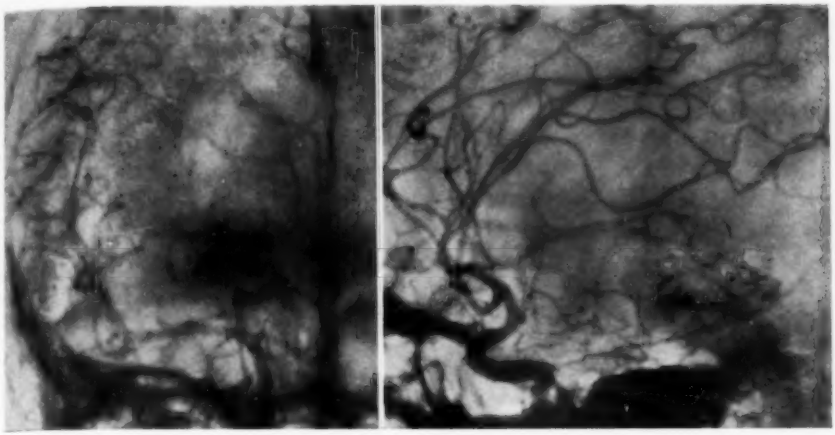


Fig. 7. Intraventricular meningeoma with enlarged anterior choroid artery and typical tumour vessels.

easily seen but in which there is practically no displacement of the ventricular system.

If the tumour is very large, it may completely fill the lateral ventricle so that the air gets no further than to the pole of the tumour (Fig. 3). In such a case, a definite differential diagnosis cannot, in our opinion, be made from pneumography; our experience is, however, that tumours originating in the parenchyma of the brain seldom grow into the ventricular system to such a degree that it becomes completely filled. Yet, it may occur as may be seen from Fig. 4. But in such a case there is also considerable lateral displacement of the lateral ventricles which is a sign against an intraventricular tumour.

Figs. 5 and 6 show the possibility of distinguishing between a true intraventricular tumour and a tumour which only partly is situated inside the ventricular system and the main extension of which is extraventricular.

Among the 7 cases in this material investigated with pneumography there were 4 in which the pneumograms showed without a doubt that an intraventricular tumour was present, and 3 in which the diagnosis was more or less probable.

In their statements on angiographic changes, WALL as well as HUANG and ARAKI cite one as being probably characteristic of these tumours, namely an enlarged anterior choroid artery or pathologic vessels filling from this artery. We have carried out angiography in only 4 cases. In 3 of them, the anterior choroid artery was enlarged and lengthened,

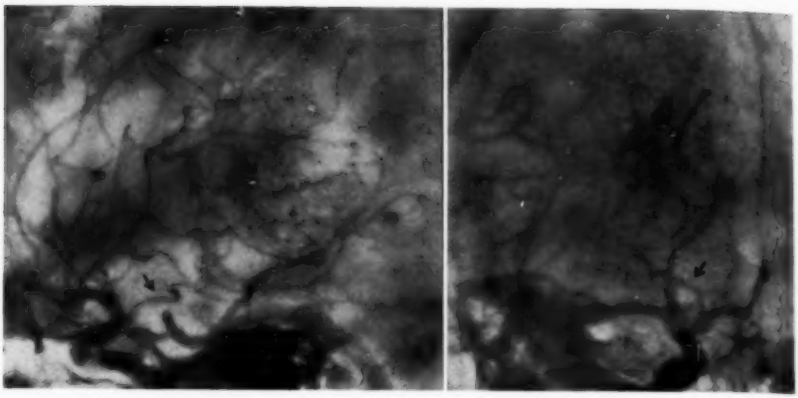


Fig. 8. Glioma with enlarged anterior choroid artery but tumour vessels characteristic of malignant tumours with irregular connections between arteries and veins.

and in 1 of these (Fig. 7) a tangle of vessels of the appearance common in meningeomas also became filled, and in the venous phase the whole tumour as well. Judging by WALL's and the Japanese authors' experiences, as well as by our own, it thus appears that changes in the anterior choroid artery are common in meningeomas within the lateral ventricles, which corresponds to what one would assume *a priori*, since these tumours originate from the choroid plexus. But, according to our experience, it is not right to make a diagnosis of intraventricular meningeoma only on the basis of a lengthened and enlarged anterior choroid artery; this vessel can also be altered by other tumours (Fig. 8).

In one of our cases, the anterior choroid artery was not changed, nor did any pathologic vessels fill. If the tumours are not situated in the temporal horn, changes in the anterior choroid artery may be absent. This is probably due to the fact that the posterior part of the plexus receives its blood supply from the lateral posterior choroid artery, which is a branch of the posterior cerebral artery. Therefore, if this vessel does not fill in carotid angiography, vertebral angiography should be carried out. WALL has furthermore shown that vertebral angiography may be of very great value in demonstrating these tumours, since changes in the roentgenologic appearances of the choroid plexus seem to be typical for meningiomas within the lateral ventricles.

Judging by the experiences of WALL and HUANG and ARAKI as well as our own, it appears that it is nowadays possible to make a definite pre-operative roentgenologic diagnosis, in some cases by means of pneumography, in others by angiography, and, finally, in certain cases only through combining the results of both methods.

SUMMARY

The author discusses the pneumographic and angiographic findings in meningeomas in the lateral ventricles. An intraventricular growth or extension can always be demonstrated, and simultaneous changes in the choroid arteries or plexus should, in the author's opinion, always make a roentgenologic diagnosis possible.

ZUSAMMENFASSUNG

Der Verfasser diskutiert die pneumographischen und angiographischen Befunde bei Meningeomen der Seitenventrikel. Ein intraventrikuläres Wachstum oder eine intraventrikuläre Ausbreitung kann stets demonstriert werden; gleichzeitig auftretende Veränderungen in den Choroidalarterien oder im Plexus sollten, nach der Ansicht des Verfassers, eine röntgenologische Diagnose immer möglich machen.

RÉSUMÉ

L'auteur étudie les signes pneumographiques et angiographiques des méningiomes des ventricules latéraux. Il est, dans tous les cas, possible de mettre en évidence une tumeur ou une extension intraventriculaire, et des modifications associées des artères choroïdes ou des plexus devraient, selon l'auteur, toujours rendre possible un diagnostic radiologique.

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FROM THE NEUROSURGICAL DEPARTMENT (DIRECTOR: PROF. G. M. FASIANI), SURGICAL CLINIC OF THE UNIVERSITY OF MILANO, ITALY

VERTEBRAL ANGIOGRAPHY IN SUPRATENTORIAL EXPANSIVE PROCESSES

by

F. Columella and *I. Papo*

Our experience is based upon 105 cases of supratentorial expansive processes, in which first carotid and then vertebral angiography was carried out:

Table

Vertebral angiographies		391
Supratentorial expansive processes		105
a) hemisphere tumours		59
frontal	5	
fronto-temporal	3	
temporal	26	
parietal	14	
occipital	10	
subdural haematoma	1	
b) midline tumours		46
of the suprasellar region with homonymous hemianopsia	15	
of the clivus	4	
of the basal ganglions	8	
of the pineal region	8	
of the corpus callosum	2	
in the 3rd ventricle	7	
in the lateral ventricle	2	

We believe that vertebral arteriography should always be carried out after examination of the carotid artery in the following three types of cases.

I. When carotid angiography shows the presence of a supratentorial expansive process but the posterior cerebral artery is not demonstrated

and, at the same time, the examiner remains in doubt as to whether the tumor is temporal, parietal, or occipital.

II. When carotid angiography shows the presence of a supra-tentorial expansive process, but the posterior cerebral artery is not demonstrated and it appears logical on clinical grounds to suspect that the tumour may extend beyond the limits shown by carotid angiography, *i. e.*, superficially towards the posterior parts of the cerebral hemisphere or deeply towards the midline structures.

III. When carotid angiography shows the presence of hydrocephalus (especially if the internal cerebral vein and/or the basal vein appears to be displaced).

We are convinced by our experience that in each of these circumstances vertebral angiography can give important diagnostic data. In fact thanks to this radiologic examination we have often diagnosed the exact site of tumours situated posteriorly in the cerebral hemispheres in cases in which carotid angiography has not given quite definite results. We shall now deal in some detail with the appearances encountered in these three types.

Type I. a) *Parietal expansive processes* (Fig. 1 a) generally lower the internal occipital artery (as seen in the lateral view) and make the arterial network running through the parieto-occipital sulcus almost horizontal. These signs are only significant if present together.

b) *Posterior temporal expansive processes* do not present definite signs in the lateral view but in the half-axial projection (Fig. 1 b) a widening of the dicotomy between the internal occipital and temporo-occipital arteries is often apparent; this is also seen in cases of extrinsic tumours.

c) *Occipital expansive processes* present a pathognomonic sign in the lateral view (Fig. 1 c); a step-shaped displacement of the internal occipital artery, its central part being directed upwards and its distal part raised. In lateral vertebral arteriograms it is often possible to compare the displaced artery with the one on the healthy side. In the half-axial projection (Fig. 1 d) these tumours cause a deformation of the basilar fork which we have never found in tumours situated in other regions. We attribute this displacement to herniation of the isthmus of the cingulate gyrus with consequent forward rotation of the homolateral cerebral peduncle (3).

It is possible to compare the deformation of the basilar fork in (b) and (d) of Fig. 1. In posterior temporal tumours (b) the homolateral posterior cerebral artery in the half-axial projection appears to be displaced towards the contralateral side, often together with the distal part of the basilar artery. On the other hand in occipital tumours (d) in the half-axial arteriograms the posterior cerebral artery appears to be lowered. The displacement in this projection means that the posterior cerebral

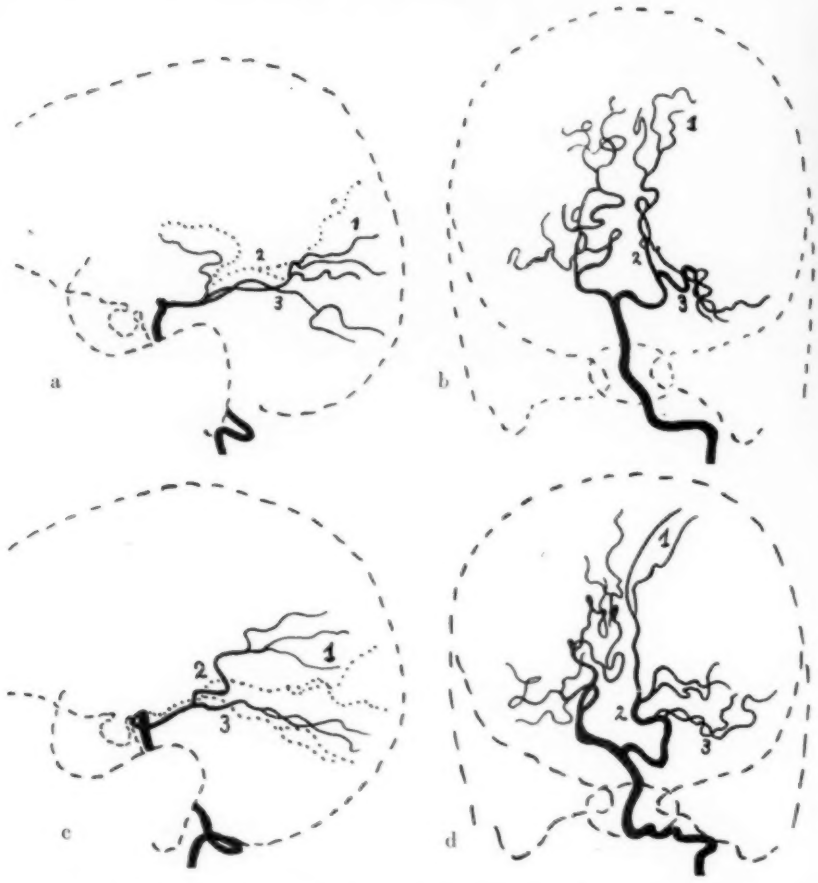

Fig. 1. a) *Parietal expansive process.* Internal occipital artery displaced downwards (2), the arterial network running in the parieto-occipital sulcus being also depressed, and becoming almost horizontal (1) (arteries on normal side dotted). b) *Posterior temporal expansive process* (half-axial projection). Deformation of basilar fork and shifting towards opposite side of part of posterior cerebral artery lateral to cerebral peduncle and initial part of internal occipital artery; dicotomy of posterior cerebral artery is enlarged by stretching of temporo-occipital (3) and internal occipital (2) arteries. c) *Occipital expansive process.* Step-shaped displacement of internal occipital artery (2); initial part of artery is on the normal side, intermediate part has become vertical, and distal part and parieto-occipital arterial network are raised (arteries on normal side dotted). d) *Occipital expansive process* (half-axial projection). Deformation of basilar fork by depression and alteration in peripeduncular arch of posterior cerebral artery. Initial and distal parts of internal occipital artery (2) moved towards median line.

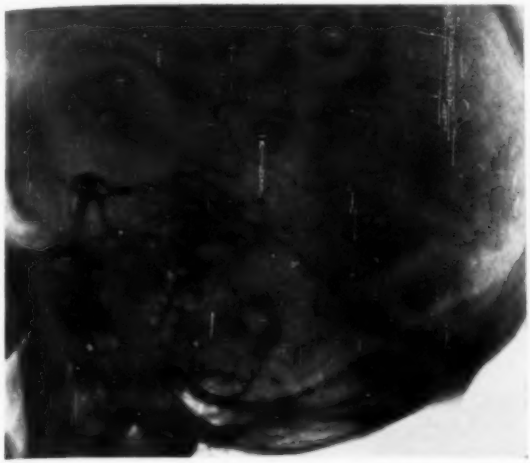

Fig. 2. *Occipital glioblastoma.* Peripeduncular part of the posterior cerebral artery appears to be displaced forwards. Compare posterior cerebral arterial systems on the two sides: step-shaped deformation of internal occipital artery on tumour side; other side normal.

artery is only moved anteriorly. The initial part of the posterior cerebral artery, which passes in front of the cerebral peduncle, is often seen to be displaced anteriorly to the same part of the posterior cerebral artery of the healthy side as well as to the distal part of the basilar artery (Fig. 2).

Type II. In demonstrating a pathologic circulation, vertebral angiography may also show an unexpected extension of the tumour toward the posterior region of the cerebral hemisphere, or an invasion of the homolateral ventricle and midline structures. Fig. 3 a represents the lateral carotid angiogram of a case of parietal glioblastoma, in which a defined pathologic circulation appears. In the lateral vertebral arteriogram of the same case (Fig. 3 b) the pathologic circulation reveals an unexpected posterior extension of the tumour and an invasion of the posterior part of the corpus callosum. In another case of parietal glioblastoma (Fig. 4 a) carotid angiography showed the tumour to be cortical or subcortical, but vertebral angiography (Fig. 4 b), by outlining a pathologic circulation as well, demonstrated three new facts: the tumour was much larger than presumed from the carotid angiography, it extended deeply into the midline structures, and the lateral ventricle was invaded. (The posterior medial choroidal artery was depressed into a curve, the concavity of which was directed upwards and backwards.)

Type III. In every case in which carotid angiography demonstrates hydrocephalus and the posterior cerebral artery is not shown, subsequent vertebral angiography will sometimes reveal a supratentorial expansive process. In the whole of our series the most interesting results appear to be those furnished by growths of the pineal region and tumours situated across the hyatus tentorii. The former may be divided into two groups.

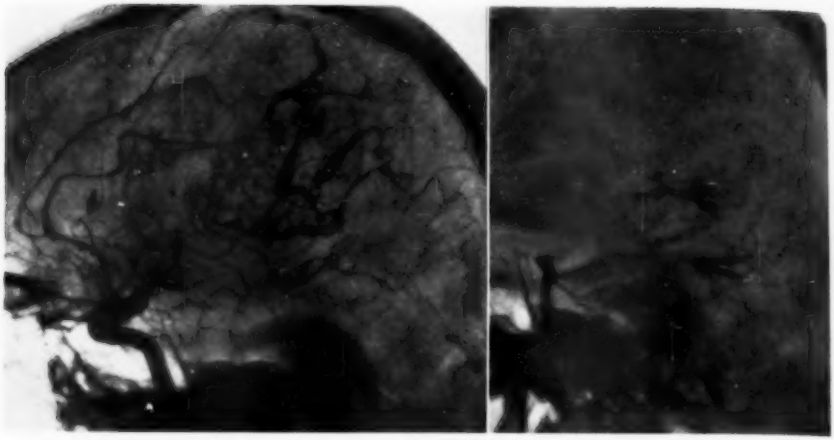

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Fig. 3. *Parietal glioblastoma.* a) Lateral carotid angiogram. Pathologic circulation of defined size — compare with b). Lateral vertebral arteriogram. Another part of pathologic circulation of same tumour showing extension of glioma into posterior part of corpus callosum.

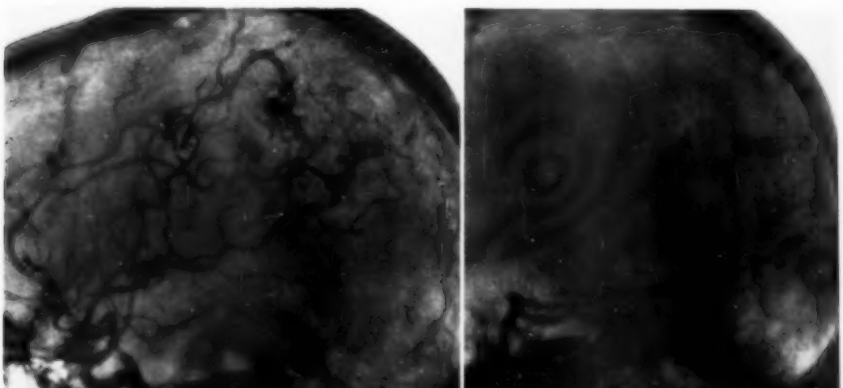

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Fig. 4. *Parietal glioblastoma.* a) Lateral carotid angiogram. Cortical and sub-cortical pathologic circulation. b) Lateral vertebral arteriogram showing further extension of tumour; unexpected invasion of median line structures and lateral ventricle (stretching and depression of posterior medial choroidal artery).

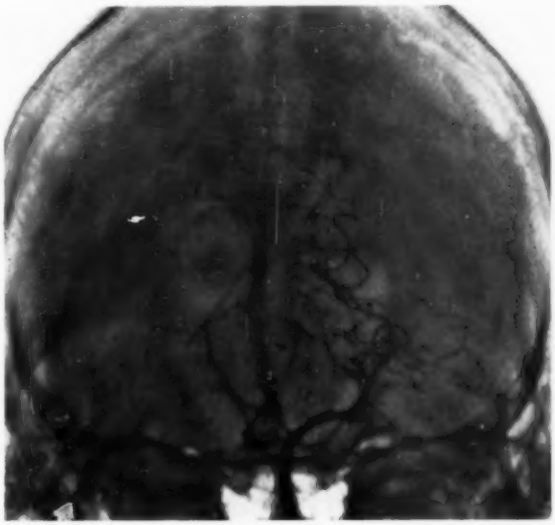

Fig. 5. *Deep temporal epidermoidal tumour* extended into posterior fossa through hiatus tentorii (verified): stretched right posterior cerebral artery; widened dicotomy between right temporo-occipital and right internal occipital arteries (signs of posterior temporal expansive process); distal part of superior cerebellar artery (arrows) displaced to opposite side over median line (sign of subtentorial expansion).

a) *Tumours in front of the brain stem*, in which the basilar artery is raised from the clivus. This happened in cases of chordoma, meningeomas and craniopharyngeomas (2). The basilar artery also showed some slight lateral displacement; but this did not happen constantly. In these cases, in which there was severe endocranial hypertension, vertebral angiography was useful for avoiding pneumographic studies.

b) *Tumours lateral to the brain stem*, in which the existence of the supratentorial expansion is demonstrated when the distal part of the superior cerebellar artery is pushed to the opposite side beyond the median line, or when its proximal part, together with the posterior cerebral artery, is raised. This was seen in two cases. One was of a verified aneurysm, the size of a large plum, which was not filled with contrast medium either by carotid angiography or vertebral angiography. The other case was of a deeply situated epidermoidal tumour, in which carotid angiography only demonstrated hydrocephalus. In the half-axial vertebral arteriogram (Fig. 5), however, the stretched posterior cerebral artery and the widening of the space between the internal occipital and temporo-occipital arteries were clearly seen; this means that the expansive

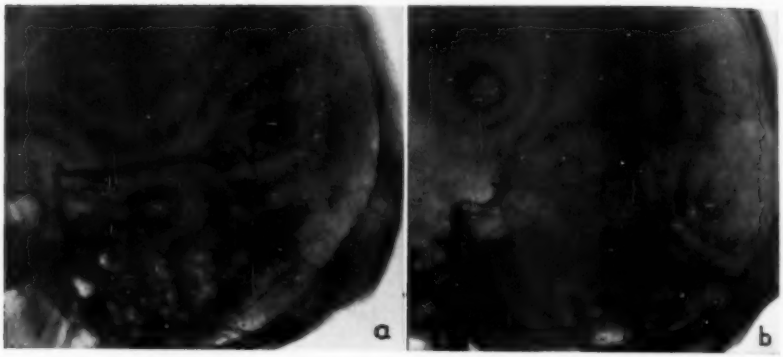

Fig. 6. a) *Spongioblastoma of posterior part of thalamus.* Internal occipital artery appears almost horizontal and depressed forming inferior limits of pathologic circulation. (To the right schematic drawing of lateral ventriculogram — tumour of the pineal region.)

Fig. 6. b) *Meningeoma of free edge of tentorium.* Internal occipital artery considerably raised and forming superior limits of pathologic circulation.

process was a posterior temporal one. The subtentorial expansion of the tumour is demonstrated by the superior cerebellar artery (arrows) displaced beyond the median line.

In *expansive processes of the pineal region* the position of the internal occipital artery permits of a differential diagnosis between a meningeoma of the free edge of the tentorium and tumours of the pineal gland or surrounding cerebral structures (1). In the latter the internal occipital artery is lowered (Fig. 6 a), while in the former it is raised (Fig. 6 b).

In conclusion, we would point out that vertebral angiography should be carried out only as a complement to carotid angiography and furthermore, as in the case of carotid angiography, normal vertebral angiography does not exclude the presence of an expanding process or permit of a diagnosis in the absence of definite displacements, unless a pathologic circulation can be demonstrated.

The assistance we have received from vertebral angiography in the diagnosis of supratentorial expansive processes appears to have been of practical value particularly as a considerable number of ventriculographies have been avoided.

SUMMARY

The authors consider vertebral angiography to be a valuable complement to carotid angiography in certain types of supratentorial expansive processes. These are discussed in detail upon the basis of a material of 105 cases.

ZUSAMMENFASSUNG

Die Verfasser sind der Ansicht, dass die Vertebralisangiographie bei gewissen Typen von supratentoriellen expansiven Prozessen ein wertvolles Komplement der Karotisangiographie darstellt.

RÉSUMÉ

Les auteurs considèrent que l'angiographie vertébrale est, dans certains types de tumeurs sus-tentorielles, un complément intéressant de l'angiographie carotidienne. Ces types de tumeurs sont étudiés en détail, sur la base d'un matériel de 105 cas.

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VERTEBRAL ANGIOGRAPHY IN THE DIAGNOSIS OF HYDROCEPHALUS AND DIFFERENTIATION BETWEEN STENOSIS OF THE AQUEDUCT AND CEREBELLAR TUMOUR

by

F. Olov Löfgren

Vertebral angiograms sometimes show the features of hydrocephalus. The question then arises whether it is possible to trace the cause of the condition from them. The purpose of the present investigation was to determine when hydrocephalus may be detected angiographically and whether vertebral angiography can distinguish stenosis of the aqueduct from tumour of the cerebellum.

Material. The material consisted of angiograms of 12 cases of stenosis of the aqueduct and 36 cases of tumour of the cerebellum. Pneumography had been done in all cases. All of the tumours of the cerebellum had been histologically verified. The cases of stenosis of the aqueduct were operatively and clinically verified. The material did not include cases in which only vertebral angiography had been performed. Vertebral angiography was carried out by the catheterisation method of RADNER, the contrast medium used being Umbradil 35 per cent.

The vascular pattern in hydrocephalus. As to the changes in hydrocephalus, RADNER says: "Angiographic changes of the arteries were disclosed in cases with pronounced ventricular dilatation, whereas a slight dilatation provoked no appreciable changes. These changes were similar to those described by MONIZ dealing with carotid angiography and consisted chiefly in diffuse arterial stretching." SJÖGREN writes: "Marked hydrocephalus produces a stretching of the intracranial branches from the carotid artery and a similar change also occurs in the region of the tentorial notch. It is incorrect, however, to assume that even a considerable hydrocephalus alone generally causes an accentuated stretching of the vessels."

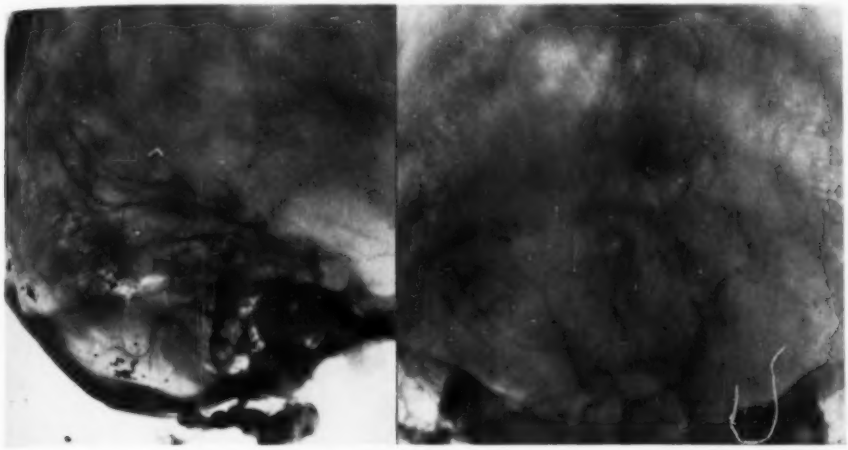

Fig. 1. Severe hydrocephalus. Posterior cerebral arteries straightened. Posterior border of the tentorial notch, *i. e.* at confluence of great cerebral vein and straight sinus obtained from the phlebogram (A).

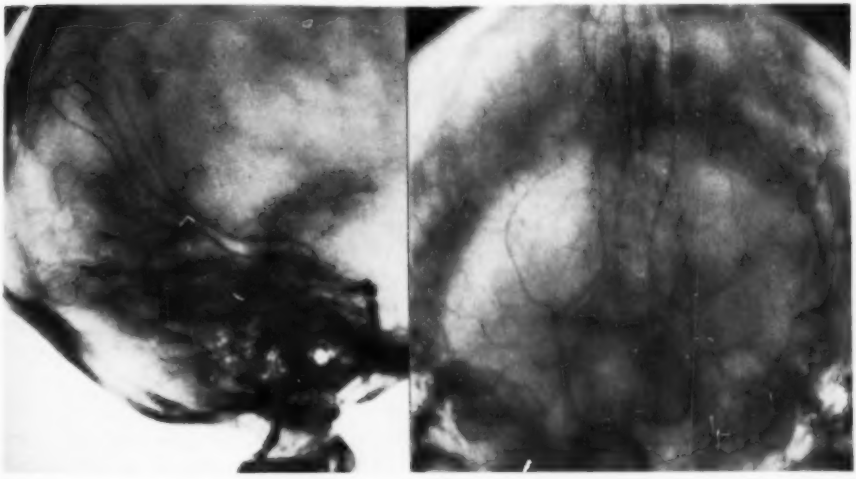

Fig. 2. Severe hydrocephalus. Posterior cerebral arteries straightened and slightly pushed down into tentorial notch.

In hydrocephalus the normally tortuous posterior cerebral artery and its branches are more or less straightened (Fig. 1). In severe hydrocephalus the posterior cerebral artery is even sometimes pushed down into the tentorial notch (Fig. 2).

In order to assess when vascular changes can be recorded, the cases were arranged in a table according to the degree of hydrocephalus. The largest breadth of the lateral ventricle, as measured in the frontal ventriculogram, is given in relation to the greatest internal breadth of the corresponding half of the cranium (LINDGREN). The degree of hydrocephalus is expressed as the quotient of the breadth of the lateral ventricle and the breadth of half of the cranium (Table 1).

Table 1

Degree of hydrocephalus expressed as quotient of breadth of the lateral ventricle and breadth of half the cranium

	Stenosis of the aqueduct			
		Posterior cerebral artery		
Degree of hydrocephalus	Number of cases	not straightened	probably straightened	straightened
0.4	2	2	—	—
0.5	7	1	2	4
0.6	1	—	—	1
0.7	2	—	—	2

As is apparent from the table, hydrocephalus may be demonstrated by vertebral angiography when the greatest breadth of the lateral ventricle amounts to about one half the greatest internal breadth of the corresponding half of the cranium, or in other words not until the hydrocephalus is pronounced. The cases of tumour of the cerebellum are arranged in a similar way in Table 2.

Table 2

	Tumour of the cerebellum			
		Posterior cerebral artery		
Degree of hydrocephalus	Number of cases	not straightened	probably straightened	straightened
0.3	4	4	—	—
0.4	17	12	1	4
0.5	10	1	3	6
0.6	5	1	—	4

The table shows that hydrocephalus may be demonstrated at the same degree of ventricular dilatation in cerebellar tumour as in stenosis of the aqueduct.

The vascular pattern in tumour of the cerebellum. The vascular change seen in hydrocephalus, *i. e.* straightening of the posterior cerebral artery, is due to supratentorial expansion caused by the dilated ventricles. What vascular changes are to be expected in infratentorial expansion? If expansion is marked, the cerebellum and the brain stem protrude up-

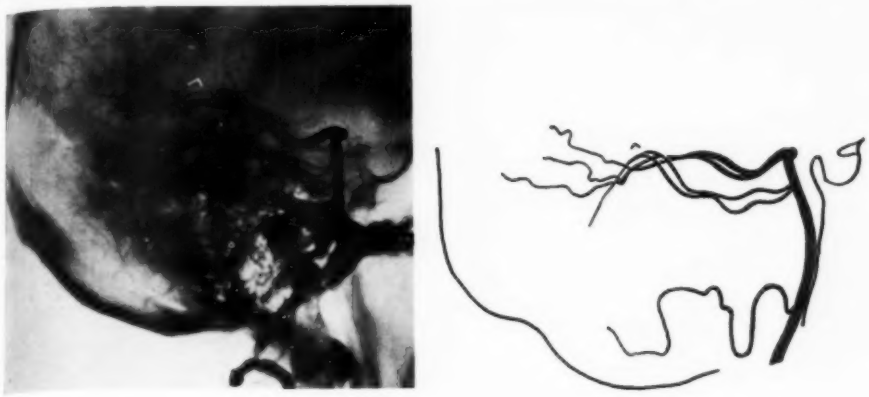

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Fig. 3. a) Normal case. Superior cerebellar arteries at first make downwardly convex curve below posterior cerebral arteries. After giving off lateral branches they continue with medial branches in upward acute arc over edge of cerebellum. b) Drawing showing main stems of posterior cerebral arteries, superior cerebellar arteries and medial branches, and posterior inferior cerebellar artery.

wardly through the tentorial notch. This herniation should reasonably be reflected in the angiogram by upward displacement of the vessels extending over the cerebellum, *i. e.* the medial branches of the superior cerebellar artery. On the other hand, the tonsils may be displaced downwards through the foramen magnum. Herniation of the tonsils should likewise be reflected by a depression of the posterior inferior cerebellar artery.

In the demonstration of tumour of the cerebellum DECKER based the diagnosis mainly on the course of the posterior cerebral artery. He presented a material in which in fully half of the cerebellar tumours the posterior cerebral arteries were distinctly displaced upwards. HAUGE uses mainly displacement of the posterior inferior cerebellar artery in the diagnosis of tumours of the posterior cranial fossa. He writes "that the possibility of arriving at a differential diagnosis between stenosis of the aqueduct and an expanding lesion in the posterior cranial fossa seems remote".

SJÖGREN stressed above all the importance of the posterior inferior cerebellar artery, its downward displacement in foraminal herniation as well as its lateral displacement for the lateral localization of processes. He points out "that the expanding process may be surrounded by stretched arch-shaped arteries or veins in its neighbourhood". He states that "herniations upwards through the tentorial notch cause displace-

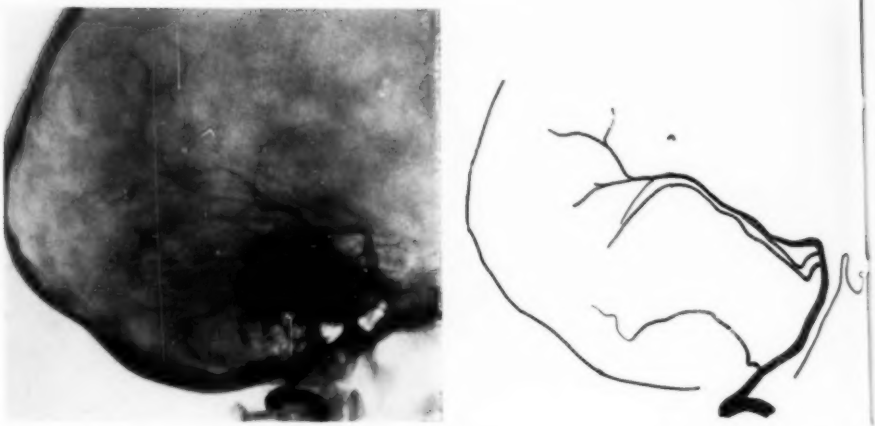

Fig. 4. Tumour of cerebellum with slight expansion. Superior cerebellar arteries at first follow normal downward course below posterior cerebral artery, but soon swing up more sharply than otherwise, pursue straight course and form more obtuse arc above cerebellum.

ment of adjacent vessels. In questionable cases the level of the tentorial notch may be gauged if the posterior clinoid process and the posterior border of the notch, obtainable from the phlebogram, are combined in a slightly curved line."

It is, however, difficult to determine the edge of the tentorium by joining two points by an arcuate line. It is apparent from the present material that even though it is not possible to demonstrate herniation of the cerebellum into the tentorial notch with certainty, an upward displacement of the medial branches of the superior cerebellar artery can be detected.

The normal vertebral angiogram has been described by RADNER. A more detailed description of the superior cerebellar artery is given here. Its course, as seen in the lateral view is as follows (Fig. 3). The superior cerebellar artery branches from the basilar artery at a level 0 to 10 mm (average 4 mm) below the posterior cerebral artery. It then passes round the upper border of the pons and backwards in a downwardly convex curve 5 to 12 mm (average 9 mm) below the posterior cerebral artery. When the artery reaches the frontal border of the cerebellum, it swings upwards, gives off its lateral branches over the dorsal surface of the cerebellum, and then often dips down between the cerebellum and the brain stem. It then continues with its medial branches in an upward, usually acute, arc over the edge of the cerebellum and proceeds over the upper surface of the vermis near the midline. The top of the arc over the upper edge of the cerebellum is on a level with, or up to

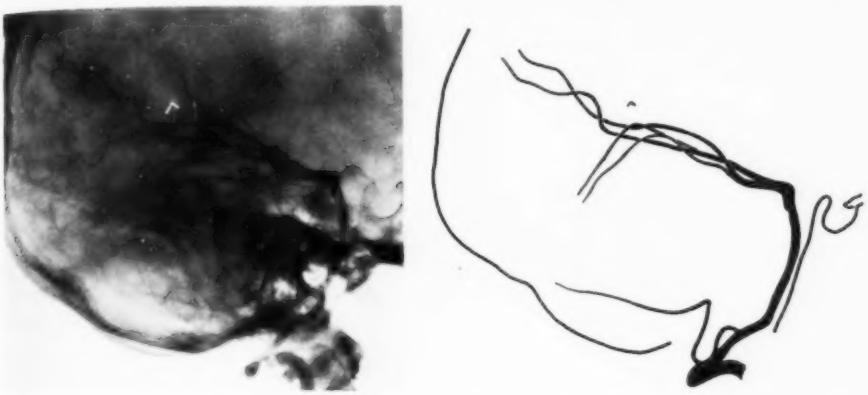

Fig. 5. Tumour of cerebellum with pronounced expansion. Curves normally present have disappeared, and superior cerebellar arteries describe a marked, upwardly convex arc, and are superimposed upon posterior cerebral arteries. Caudal loop of posterior inferior cerebellar artery swings down below foramen magnum; cranial loop slightly depressed.

10 mm (average 2 mm) above, the occipital branch of the posterior cerebral artery.

In the presence of a cerebellar tumour the superior cerebellar artery extends upward in a more or less pronounced arc. If the expansion is only slight, the artery will first follow a normal downward arcuate course, but will soon swing up more sharply than otherwise. It then pursues a straight course to form a more obtuse arc than that normally seen above the cerebellum (Fig. 4). If the expansion is pronounced, the curves normally present will have disappeared, and then, immediately after its origin from the basilar artery, the superior cerebellar artery describes a marked upwardly convex arc (Fig. 5).

In pronounced expansion an upwardly convex displacement of the posterior cerebral artery, as described by DECKER, is often seen.

In a large percentage of cerebellar tumours the posterior inferior cerebellar artery shows an abnormal course. The roentgen anatomy of this artery has been described by SJÖGREN and by HAUGE. The artery branches from the vertebral artery and then extends backwards round the medulla to enter the medial surface of the cerebellar tonsil. In frontal films it is seen to divide into a lateral and a medial branch, the latter continuing its course close to the midline (Fig. 1). In the lateral film, the artery extends backwards, first in a downwardly convex curve until it reaches the level of the foramen magnum, indicating the caudal part of the cerebellar tonsil. The artery then proceeds in an upwardly

convex curve, closely related to the choroid plexus of the fourth ventricle and indicating the upper border of the tonsil. These are called the caudal and the cranial loops by HAUGE (Figs. 1, 3).

In the event of herniation through the foramen magnum, the cerebellar tonsils are pushed down together with the caudal loop which then swings down below the foramen magnum (Fig. 5). But the tonsils may herniate into the foramen magnum without downward displacement of the caudal loop. On the other hand, the caudal loop is sometimes seen to pass below the foramen magnum in the absence of an expansive process. In tumours in the midline, especially in the fourth ventricle, the cranial loop may be pushed downwards (Fig. 5), sometimes to the very bottom of the posterior cranial fossa. If the tumour extends down between the two posterior inferior cerebellar arteries, the cranial loops may be separated. If the tumour is situated in the hemisphere, the medial branch is displaced to the opposite side.

Pathologic vessels are seen chiefly in hemangioma of the cerebellum. Contrast filling of the angioma will show the nature as well as the situation of the tumour (OLLE OLSSON). Thus, it is not necessary to consider any other vascular displacement. For this reason cases of hemangioma were not included in the present material. In other kinds of cerebellar tumours pathologic vessels are seldom seen.

In order to form an opinion of the frequency of the vascular displacements under consideration the cases of cerebellar tumour were arranged in tabular form (Table 3).

Table 3

	Number of cases	Upward displacement of posterior cerebral artery	Upward displacement of superior cerebellar artery	Inferior posterior cerebellar artery: Downward displacement of cranial loop	Inferior posterior cerebellar artery: Downward displacement of caudal loop	Midline shift
Tumour of cerebellum	36	14	31	21	17	10
Stenosis of aqueduct	12	0	0	0	2	0

The posterior cerebral arteries were displaced upwards in 14 cases.

In 31 out of 36 cases the superior cerebellar arteries were displaced arcuately upwards. Of the 5 cases without such demonstrable sign of expansion, displacement of the cranial loop of the posterior inferior cerebellar artery indicated the presence of tumour in 2 cases. In 3 cases there were no signs of an expansive tumour. In 2 of them there was hardly any ventricular dilatation. In one of these the operative findings at first suggested a stenosis of the aqueduct. At re-operation half a year later a small astrocytoma was seen around the aqueduct. In the other case a

small tumour was found caudally in the fourth ventricle in the choroid plexus. In the third case operation revealed a small astrocytoma in the roof of the fourth ventricle. A polypoid extension of the tumour occluded the aqueduct.

In these 3 cases the tumours were not so large as to produce any expansive effect and therefore they could not be detected by angiography. On the other hand, a markedly dilatated fourth ventricle can give a roentgenographic appearance simulating that of an expansive process, as pointed out by LINDGREN and by SJÖGREN.

The vascular pattern of stenosis of the aqueduct. In stenosis of the aqueduct, the course of the superior cerebellar arteries is of normal appearance (Figs. 1, 2). Never does it produce such an upward convex displacement of the arteries as in cerebellar tumour. Sometimes the tonsils are pushed down into the foramen magnum with accompanying displacement of the caudal loop of the posterior inferior cerebellar artery. The cranial loop is not displaced. The medial branch always lies in the midline. The cases of stenosis of the aqueduct are given in tabular form in the same way as the cases of cerebellar tumour (Table 3).

There were 12 cases of stenosis of the aqueduct. In 2 of them the caudal loop of the posterior inferior cerebellar artery was displaced downwards. Otherwise no displacement of the infratentorial vessels was seen. Thus, in stenosis of the aqueduct with pronounced hydrocephalus the posterior cerebral artery is straightened, but except for occasional dipping of the caudal loop of the posterior inferior cerebellar artery into the foramen magnum, the infratentorial vessels show no roentgenographic changes. The same angiographic appearance can, of course, be produced by any other kind of obstruction of the passage of the liquor, such as pinealoma or a cyst of the foramen of Monroe.

The cerebellar tumours were diagnosed by the displacement of the vessels in the posterior cranial fossa, while no such changes were seen in cases of stenosis of the aqueduct.

On vertebral angiography these 12 cases of stenosis of the aqueduct and 36 cases of cerebellar tumour could be distinguished from one another in all cases except 3. When hydrocephalus was so pronounced as to be demonstrable in the angiogram, the differential diagnosis was always possible.

SUMMARY

A review is presented of 12 cases of stenosis of the aqueduct and 36 cases of tumour of the cerebellum examined angiographically. Hydrocephalus was recognized in 9 cases of the former and in 18 cases of the latter. The differentiation between the two conditions, which was possible in all cases except 3, is discussed. When hydrocephalus was pronounced enough to be demonstrable differential diagnosis was always possible.

ZUSAMMENFASSUNG

Eine Übersicht über 12 Fälle mit einer Stenose des Aquaeductus und über 35 Fälle mit Kleinhirntumoren, welche alle angiographisch untersucht worden sind, wird vorgelegt. Hydrocephalus wurde in 9 Fällen der ersten Gruppe und in 18 der zweiten Gruppe gefunden. Die Differenzierung dieser beiden Zustände wird besprochen; mit Ausnahme von 3 Fällen war sie bei allen übrigen Untersuchungen durchführbar. Die Stellung der Differentialdiagnose war in Fällen mit nachweisbarem Hydrocephalus stets möglich.

RÉSUMÉ

L'auteur présente une étude d'ensemble de 12 cas de sténose de l'aqueduc et de 35 cas de tumeur du cervelet examinés par angiographie. Une hydrocéphalie a été reconnue dans 9 cas de sténose et dans 18 cas de tumeur du cervelet. L'auteur étudie la différenciation entre ces deux affections; elle a été possible dans tous les cas sauf 3. Quand l'hydrocéphalie était assez prononcée pour pouvoir être mise en évidence, le diagnostic différentiel était toujours possible.

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CHANGES IN THE SUPERFICIAL VEINS IN CASES OF INTRACRANIAL EXPANDING PROCESSES

by

V. Gvozdanović

The venous phase of cerebral angiography has for a long time been neglected, while phlebography of the superficial veins is even to-day the stepchild of neuroradiologic diagnosis.

Although MONIZ had given a number of examples of the great significance of detailed studies of cerebral phlebograms, these have only become of practical importance lately, chiefly due to the greater use of serial angiography. The employment of phlebography for the differentiation of various kinds of tumours, especially gliomas and meningeomas, is to-day out of the question (ENGESET, HEMMINGSSON, KRAYENBÜHL & RICHTER, LINDGREN, LORENZ, TORKILDSEN, WICKBOM).

The importance of studying the central cerebral veins, to which MONIZ called attention, was recognized only after studies by LORENZ, RICHTER, UMBACH, and particularly JOHANSSON. As regards changes in the superficial veins in cases of tumours, apart from the paper by LORENZ 1951, hardly anything has been reported.

Can we, by studying phlebograms of the superficial veins of the brain, obtained with the usual technique of cerebral angiography (2 to 3 a. p. and 3 to 4 lateral films), derive any further information about intracranial expanding processes — in short, do the superficial veins play any rôle in the diagnosis of expanding processes? The answer is, to all intents and purposes, in the negative.

In a previous work (begun in Serafimerlasarettet in 1948 and finished in Zagreb in 1951) carried out on 300 normal phlebograms and 100 normal anatomic specimens, I stressed the fact that, on account of the numerous anastomoses, the entire network of superficial veins constitutes one single functional whole. The circulation in this network is possible in every

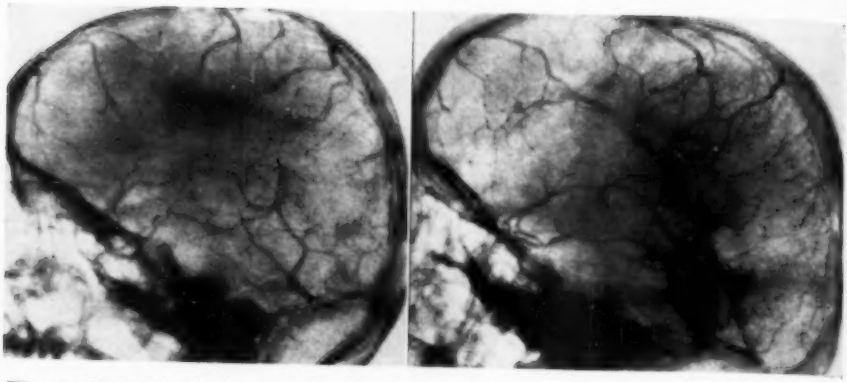
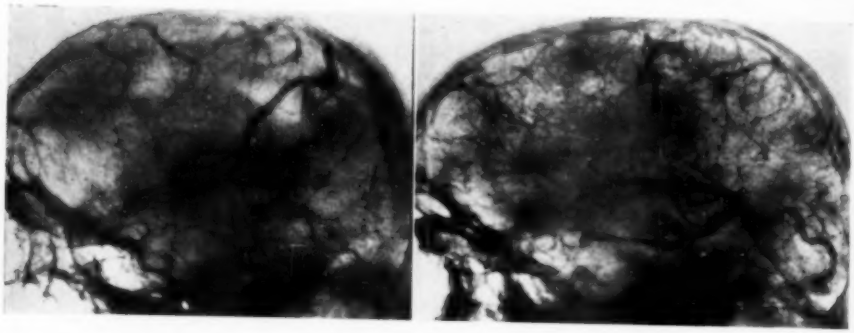


Fig. 1. Normal phlebograms. Regular distribution of superficial ascending veins and drainage of convexity.



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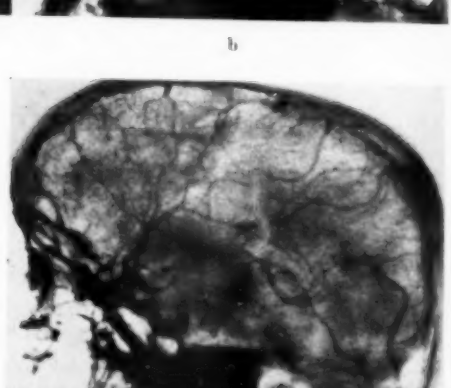


c

Fig. 2. Normal phlebograms. Domination of drainage in one direction: a) to superior longitudinal sinus — vein of Trolard; b) to the transverse sinus — vein of Labbé; c) to cavernous sinus — middle cerebral vein.

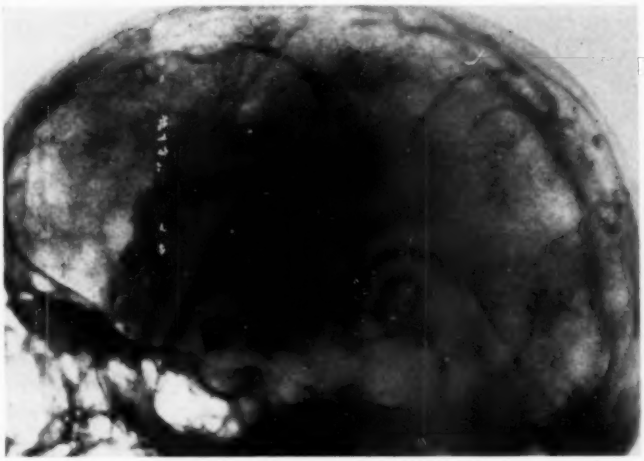
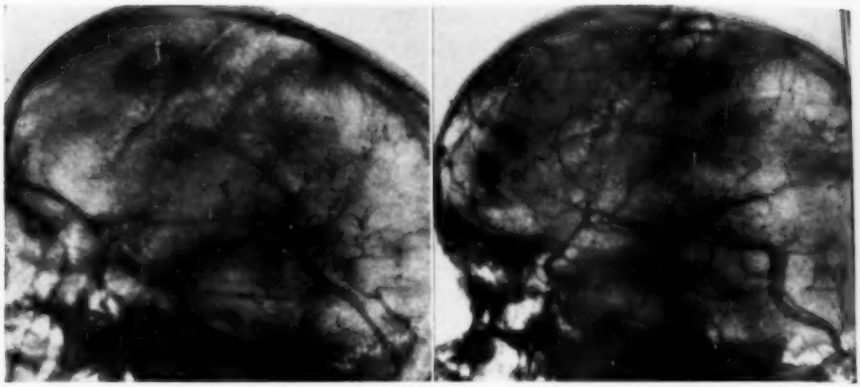


Fig. 3. Tuberculoma. Poor filling of frontal superficial veins.

direction since the superficial veins have no valves. Accordingly, there exist possibilities of adaptation to new factors (expanding processes, thrombosis) in the sense of change of drainage direction. It was also realized that the walls of the veins are very thin and, in most intracranial expanding processes, are pressed directly against the inner table of the skull. Furthermore, it was necessary to see whether there was any possibility of displacement of the superficial veins in cases of intracranial expanding processes.

The greatest difficulty in the interpretation of phlebograms of the superficial veins in expanding intracranial processes is due to the generally and vastly accepted opinion that the superficial veins form an irregular and very variable network in which it is impossible to distinguish the normal from the pathologic.

In studying more than 500 normal phlebograms I gained the impression that the drainage of the convexity in the direction of the sinus longitudinalis superior, sinus transversus, and sinus cavernosus, is fairly regular, and that the ascending veins are fairly equally distributed (Fig. 1). Cases of domination of the drainage in one direction through the vein of Trolard, the vein of Labbé, or the middle cerebral vein (Fig. 2), represent only extreme forms of one of the possible variations. In these cases, of course, the position of the other veins is not greatly changed, the difference lying only in their calibre. I therefore believe that we can renounce the thesis of complete irregularity of the superficial veins and presume that failure of superficial veins in a large region to fill, the irreg-



a b

Fig. 4. Frontal astrocytoma. On affected side the superficial veins are poorly filled (a), while on other side they are well visualized (b).

ularity of their course, and change in the direction of drainage, must have some pathologic significance. Illustrative cases will now be examined.

Poor filling of the frontal ascending veins in a case of calcified tuberculoma may be seen in Fig. 3. Similar changes in a frontal astrocytoma are shown in Fig. 4. On the affected side the superficial veins are filled poorly, while on the opposite side they are well visualized. The large parieto-occipital meningeoma (Fig. 5) is present with poor filling of the superficial veins in the pathologic region.

Displacement of the superficial veins, in addition to their compression may be seen in a cystic glioblastoma of the parietal region (Fig. 6). The marginal vein, which LORENZ describes as a network of minute veins on the surface of the tumour, is shown in

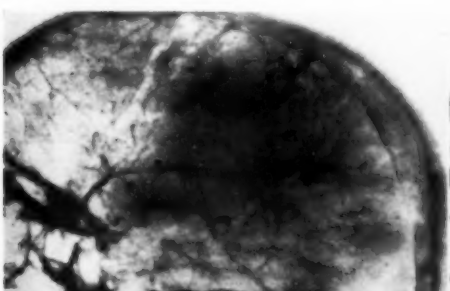


Fig. 5. Parieto-occipital meningeoma. Poor filling of superficial veins.

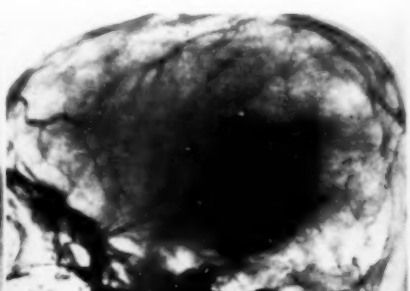


Fig. 6. Cystic glioblastoma. Compression and displacement of superficial veins.

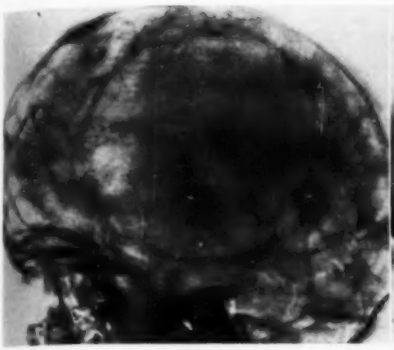


Fig. 7. Parietal echinococcus. Compression and displacement of superficial veins and a marginal vein anteriorily.

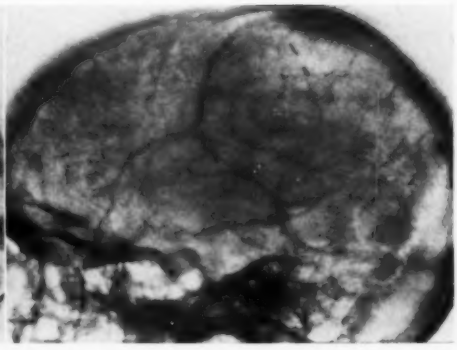


Fig. 8. Parietal astrocytoma. Marginal vein.

front of a parietal echinococcus (Fig. 7). Compression and displacement of the superficial veins is also apparent. A typical example of the marginal vein was found in a case of a parietal astrocytoma (Fig. 8). In a temporal glioblastoma multiforme (Fig. 9), the marginal vein indicated the posterior border of the tumour.

Change in the direction of drainage is illustrated by the large fronto-parietal cystic glioblastoma (Fig. 10). The superficial veins are poorly filled, and the predominant drainage towards the base is evident.

All these signs may be combined so that, for example in a parietal meningeoma (Fig. 11), we may see at the same time poor filling of the superficial veins, their displacement, the marginal vein, and the predominant drainage towards the base.

In all the cases examined, the region of poor filling of the superficial veins corresponded to the region of the flattened gyri, as determined at operations or autopsies. The marginal vein, when found in phlebograms, could also be identified.

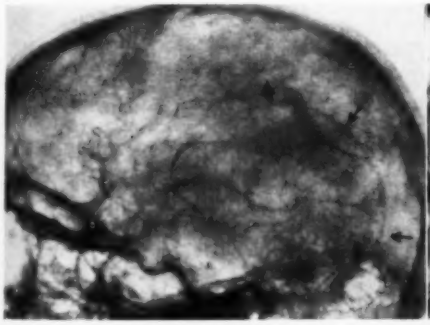


Fig. 9. Temporal glioblastoma multiforme. Marginal vein.

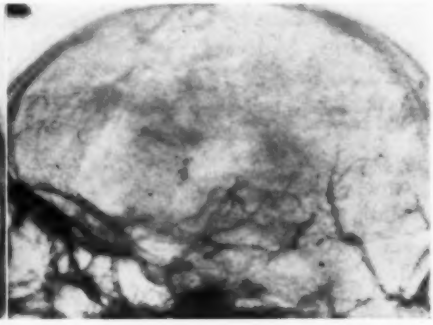


Fig. 10. Fronto-parietal cystic glioblastoma. Change in direction of drainage.

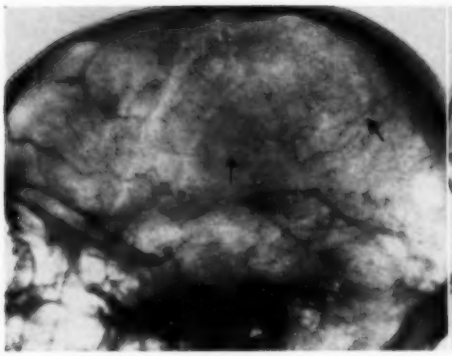


Fig. 11. Parietal meningeoma. Poor filling and displacement of superficial veins; marginal vein and predominant drainage towards base.

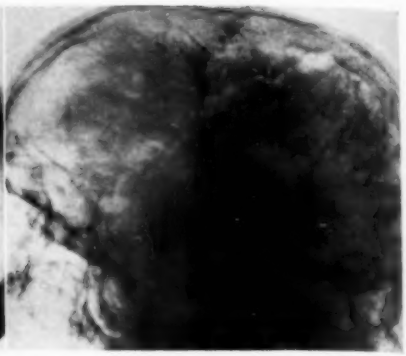


Fig. 12. Frontal posttraumatic intracerebral haematoma. Compression and thrombosis.

Deficient filling of the superficial veins may be the consequence of the slowing down or interruption of the circulation due to compression or thrombosis of the blood vessels. It may indeed be caused also by a combination of compression and thrombosis of the veins, as it was possible to verify in a case of a large frontal post-traumatic intracerebral haematoma (Fig. 12), surrounded by severe oedema, in which, besides the flattened gyri, numerous thromboses were found.

Phlebography of the superficial veins, by the demonstration of poor filling of some groups of veins, may thus provide information about the size of the region in which the venous circulation is changed. By demonstrating the marginal vein it completes the contour of the expanding process obtained by the arteriogram. It also informs us to some extent about the change of the direction of drainage. All this is particularly important in expanding processes that have no typical vascularization and lie on the convexity.

It seems that the marginal vein in single cases actually corresponds to the network of thin newly-formed veins on the surface of the tumour, as LORENZ has described. In most cases I have gained the impression, however, that it is the widening of an anatomically preformed superficial anastomosis or the displacement of a superficial vein. Such veins exist with gliomas and astrocytomas, as LORENZ has reported. I have found them also in other expanding processes, such as echinococcal cyst, tuberculoma, and in single cases of meningeoma; they should not be confused with the typical drainage vein.

Apart from cases in which the superficial veins are pressed against the bone, a complement to arteriography may be produced in cases in

which the veins are pushed away from the bone, *i. e.* in subdural haematoma. In such cases the antero-posterior phlebogram may illustrate the changes better than the arteriogram. The transitory arterio-venous phase, or early phlebogram, may be of great value in this region.

With due consideration to all we have stated, it seems that greater care should be given to the interpretation of the phlebogram of the superficial veins. There is no question of introducing new projections or supplementary films, but rather of a more accurate analysis of the routine phlebograms, often produced in small neuroradiologic departments without the elaborate technical set-up which the large centres have at their disposal.

I believe that by the employment of rapid serial films, and by studying the incipient filling of the small venous tributaries in the early phlebogram, it should be possible still better to estimate the changes in the superficial veins in cases of expanding processes.

SUMMARY

A study of 500 normal cerebral phlebograms suggested that the distribution of the superficial veins is not as irregular and variable as generally supposed. Phlebography in cases of intracranial expanding processes showed that poor filling and displacement of the superficial veins, visualization of the marginal vein, and change in the direction of drainage, may provide valuable information concerning the affected region and complete the findings obtained by arteriography.

ZUSAMMENFASSUNG

Ein Studium von 500 normalen cerebralen Phlebogrammen ergab, dass die Verteilung der oberflächlichen Venen nicht so unregelmässig und variabel ist, als man allgemein annimmt. Phlebographien in Fällen mit intrakraniellen expansiven Prozessen zeigten, dass geringe Füllung und Verlagerung der oberflächlichen Venen, deutliche Sichtbarkeit der marginalen Venen und Veränderungen in der Ablaufsrichtung wertvolle Auskünfte über das erkrankte Gebiet geben und die arteriographischen Befunde komplettieren können.

RÉSUMÉ

L'étude de 500 phlébographies cérébrales normales fait penser que la distribution des veines superficielles n'est pas aussi irrégulière ni variable qu'on le suppose en général. La phlébographie dans les cas de tumeur intracranienne a montré que le remplissage défectueux et le déplacement des veines superficielles, la visualisation de la veine marginale, les modifications de la direction du drainage peuvent fournir des données intéressantes sur la région atteinte et compléter les signes obtenus par l'artériographie.

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PHLEBOGRAPHY IN TUMOURS OF THE HEMISPHERES AND CENTRAL GREY MATTER

by

E. Laine, J. M. Delandtsheer, P. Galibert and *G. Delandtsheer-Arnott*

During recent years, it has been recognized, due in a large measure to the work of EGAZ MONIZ, that in the diagnosis of cerebral tumours, examination of the cerebral veins is as important as that of the arteries.

At the Congrès d'Alger de la Soc. de Neurochirurgie de langue Française in April 1954, a preliminary paper was read on this subject; the short bibliography included the names of LORENZ, UMBACH, RICHTER and JOHANSON, all of whom have made a special study of deep tumours. MASPES and DONEGANI published in 1952 an excellent article on phlebography in normal and pathologic conditions, which only lately was brought to our attention. In 1954, JOHANSON added to his first review (1953) the study of displacements resulting from superficial tumours. Finally, mention should be made of two recent American publications. one by RIEMENSCHNEIDER and ECKER in 1954, and the other by WOLF, NEWMAN, and BENNO SCHLESINGER in February 1955.

Normal phlebogram

Lateral view. To determine the position of the angle between the striate vein and the internal cerebral vein (the venous angle) which corresponds to the posterior margin of the foramen of Monro, it is necessary to select points in the skull which may be identified with ease.

1) JOHANSON used the straight line from the limbus sphenoidalis to the bregma, in conjunction with a hypothetical line crossing the first at right angles, at the level of the limbus sphenoidalis.
2) MASPES used the nasion-inion line.
3) WOLF, NEWMAN, and SCHLESINGER chose the line joining the tuberculum sellae and the lower margin of the sulcus for the transverse sinus.

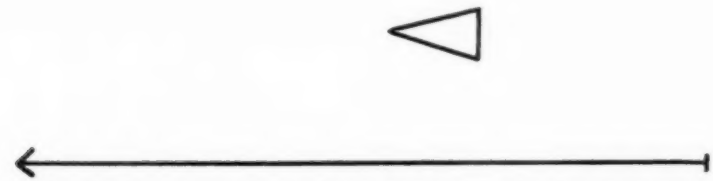

Fig. 1. Normal full-sized topogram (adult). Arrow from confluence of great cerebral vein and straight sinus to limbus sphenoidalis. The venous angle is inside the normal topogram.

We consider, however, that a single system of coordinates is insufficient to avoid errors in measuring the displacement of the apex of the venous angle produced by space-occupying lesions. Displacements of the apex of the angle caused by such lesions occur as follows: infero-superiorly, following the arc of a circle with its centre at the confluence of the great cerebral vein and the straight sinus; antero-posteriorly, following an axis practically parallel with the line which joins the limbus sphenoidalis to the internal occipital protuberance.

On the basis of 69 normal plebographies obtained with a focus—object distance of 80 cm, we have prepared a chart of the normal variations of the junction between the striate and internal cerebral veins in relation to the straight line joining the limbus sphenoidalis to the confluence of the great cerebral vein and the straight sinus. This chart has a triangular shape; its posterior base is 7 mm wide, and the height 13 mm. It represents the normal 'topogram' of the foramen of Monro (Fig. 1). Drawn on tracing paper, it may be easily superimposed on the lateral phlebogram, enabling one readily to see if the foramen of Monro is in a normal position, or if it has been displaced (Fig. 2).

It should be pointed out that this method cannot be used in children below the age of 15, since the relationship between the veins and the skull differs considerably from that found in adults.

The angle between the extremity of the internal cerebral vein and the striate vein varies in accordance with the extent to which the latter is elevated or depressed by a tumour in the vicinity. JOHANSON and RICHTER have since 1952 insisted on the value of the information to be obtained from such measurements, and we are entirely in agreement with them. Nevertheless, it should be noted that errors may arise when the striate vein is not clearly visible whilst at the same time the thalamo-trigonal vein is well shown. The normal curve of the latter, and the way it joins the internal cerebral vein, is somewhat similar to that of the striate vein. This error is even more liable to be made when, as a result of displacement of the internal central vein, the thalamo-trigonal vein is dilated.

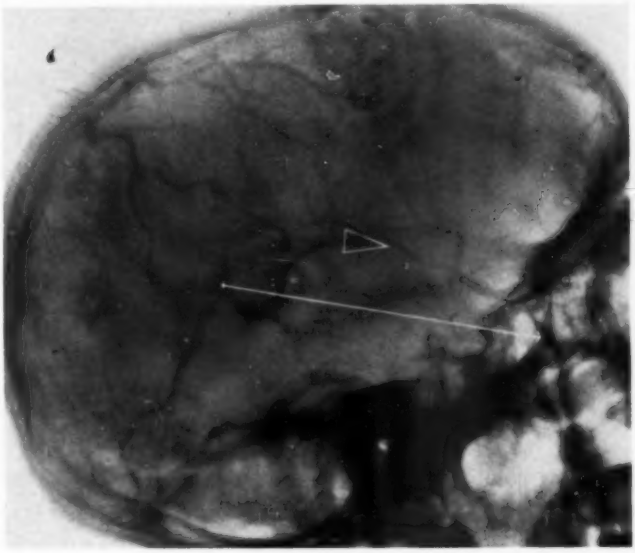

Fig. 2. Normal topogram and normal phlebogram superimposed.

The basal vein of Rosenthal, the third main component of the deep cerebral venous system, is not nearly as constant in its position as are the internal cerebral and the vein of Galen. It originates at a point about 1 cm above the level of the sella turcica. Posteriorly, it joins the great cerebral vein, and the acute angle thus formed is according to UMBACH between 40° and 45°.

The Sylvian vein. In the study of the superficial cerebral veins, special regard has been paid to the veins of Labbé and Trolard. On the other hand, little attention has been directed to the Sylvian vein, although its shape and location form a constant pattern. It runs anteriorly and inferiorly towards the spheno-parietal sinus, forming a curve, convex forwards, which in the lateral phlebogram appears to join the anterior margin of the temporal fossa, thus forming a continuous osteo-venous curved line. Superficial anterior temporal or lateral frontal tumours invariably displace it, as TÖNNIS and STEIMANN have pointed out.

Antero-posterior view. In the antero-posterior view, the usual pattern is well known. The internal cerebral vein is superimposed on the superior longitudinal sinus. The basal vein has its origin about 25 mm from the midline. The insular vein which joins it is often visualized at angiography, and it would be interesting to study its pathologic aspects.

Pathologic phlebogram

In our paper published in 1954, a study was made of the displacement of the cerebral veins in cases of hemisphere tumours. The research of MASPES and JOHANSON, added to our recent experience, all lead to the same conclusion.

Antero-posterior phlebogram. In the antero-posterior view, in cases of cerebral tumour, the displacement of the internal cerebral vein is usually evident, and it is of value to compare this with that of the anterior cerebral artery. If the displacement of the artery from the midline is greater than that of the internal cerebral vein, the tumour is likely to be relatively superficial and anterior. A small arterial displacement associated with considerable displacement of the deep veins indicates a deep central or posterior space-occupying lesion. We mentioned this in 1954, and JOHANSON reported it in all the cases of occipital tumour shown by angiography. With regard to parietal parasagittal tumours, there is no lateral displacement of the internal cerebral vein unless the tumours are large or there is associated cerebral oedema.

Lateral phlebogram. If at first sight displacement of the deep veins does not appear obvious, precise measurements in relation to reference marks on the skull may avoid possible errors, and space-occupying lesions in the brain may be accurately localized. The possible displacement of the deep veins produced by cortical tumours are summed up in the figure obtained from tracings of phlebograms in different cases of supratentorial space-occupying lesions (Fig. 3).

I. *Occipital tumours.* In cases of occipital tumour the lateral phlebogram is very rarely abnormal. The foramen of Monro is at the most displaced only slightly forwards, as is shown in a figure obtained from phlebogram tracings with a normal topogram superimposed. But if occipital tumours do not deform the lateral deep phlebogram, considerable lateral displacement of the internal cerebral vein will occur in the antero-posterior projection, whereas the displacement of the anterior cerebral artery is only very slight.

II. *Parietal and Rolandic tumours.* These tumours displace the whole Galen system towards the base, although its posterior extremity remains fixed. The foramen of Monro is pushed downwards and slightly forwards, and the normal arc of the great cerebral vein is straightened. These signs of parietal and Rolandic tumours in the lateral phlebogram are especially valuable since the antero-posterior phlebogram and the arteriogram remain normal. In all our observations of parietal and Rolandic tumours, the foramen of Monro could with one exception be

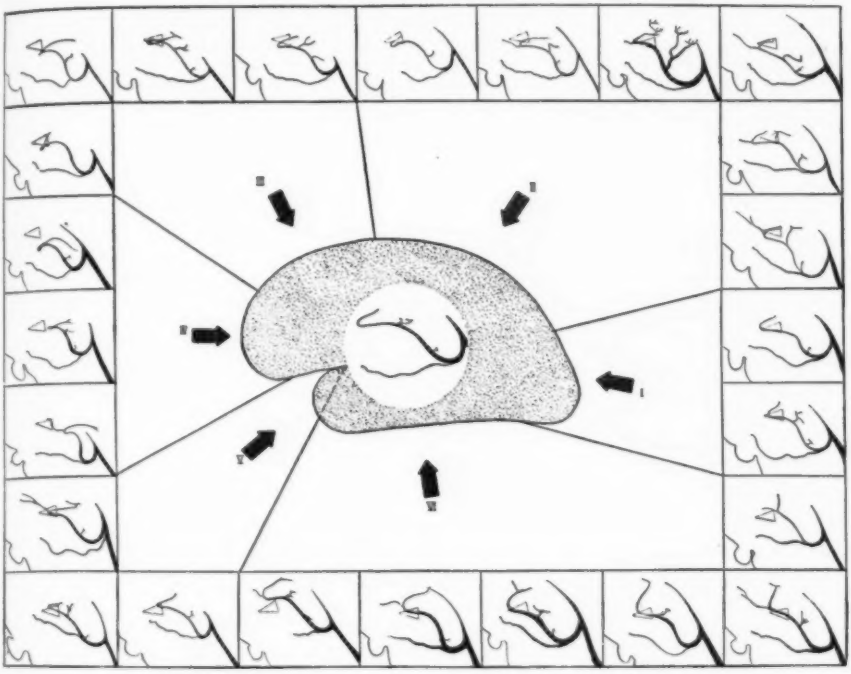

Fig. 3. I. Occipital tumours do not produce an abnormal deep lateral phlebogram but in a. p. view int. cerebral vein obviously displaced. II. Parietal and Rolandic tumours depress whole Galen system, the posterior end remaining fixed. Normal arc of great cerebral vein widened. Foramen of Monro displaced downwards and slightly forwards. III. Medial frontal and pre-Rolandic tumours displace foramen of Monro slightly backwards and cause maximum depression of venous angle, which becomes more acute. IV. Frontal polar tumours displace foramen of Monro backwards. Int. cerebral artery inclined upwards and venous angle very acute. V. Parasellar tumours cause slight or no displacement of foramen of Monro but elevate origin of basal vein. In a. p. view lateral displacement of basal vein is often striking. VI. In temporal tumours striate vein elevated and the venous angle widened according to size of tumour; posteriorly-situated tumours cause the greatest displacement. Foramen of Monro is displaced upwards only if thalamus is invaded or elevated.

(From: Neurochirurgie 1(1955), 5.)

located below the normal topogram. In the exceptional case, it was found at operation that the tumour was very small.

The downward displacement of the foramen of Monro may be seen in Fig. 3. Unusually large tumours caused maximum displacement of the venous angle. This downward displacement of the venous angle is not isolated. The whole deep venous system is, in fact, displaced basally

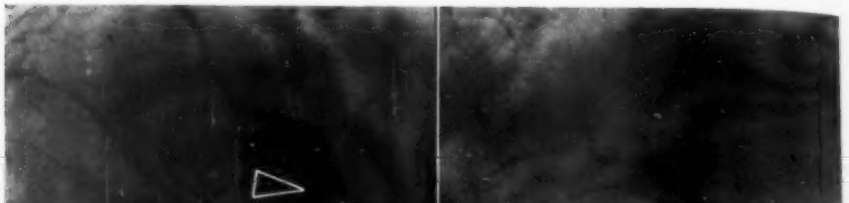

Fig. 4 (left). Pineal tumour: Internal cerebral vein raised, stretched and somewhat irregular. Great cerebral vein simultaneously compressed.

Fig. 5 (right). Pineal tumour. Lower part of great cerebral vein raised and irregular. Distance between great cerebral vein and pineal calcification increased.

Fig. 6 (left). Hematoma of fifth ventricle. Foramen of Monro displaced downwards. Venous angle normal.

Fig. 7 (right). Tumour of anterior part of corpus callosum. Anterior part of internal cerebral vein displaced downwards. Venous angle normal.

and only its posterior extremity remains in normal position because the dural sinuses are fixed. The internal cerebral vein is often stretched and the great cerebral vein elongated.

In one case of a very large posterior parietal tumour, the great cerebral vein itself was displaced downwards but not stretched, probably due to bulging of the splenium of the corpus callosum from pressure of the tumour.

In all Rolandic and parietal tumours, it has been found that the striate vein has a normal shape, as has the angle it forms with the internal cerebral vein. JOHANSON has noted that the internal cerebral vein is displaced basally in nearly all parietal expanding lesions (only Case 47 shows no abnormality in the lateral phlebogram). MASPES too has pointed out that the foramen of Monro is displaced downwards. A striking example of this is given by Case 17 (a frontoparietal parasagittal meningioma).

III. *Posterior and medial frontal tumours.* Medial frontal tumours situated just in front of Area 4 displace the venous angle slightly posteriorly and move it downwards considerably. The venous angle becomes more acute. The position of the foramen of Monro is with these tumours obviously under and behind the lower part of the normal topogram.

IV. *Anterior frontal and frontal polar tumours (Area 9 and 10) and frontal pole.* The usual pattern of the deep lateral topogram is considerably altered in such cases. The venous angle is more acute, and marked backward and downward displacement of the deep veins has a triple effect: 1) the arc of the great cerebral vein tends to close; 2) the foramen of Monro is pushed posteriorly whilst the internal cerebral vein appears to be shorter than normal; 3) the foramen of Monro is displaced downwards and the internal cerebral vein is steeper. These deformities in the lateral phlebogram become clear when one superimposes the normal topogram tracing. The position of the foramen of Monro is invariably to be found under and entirely behind the topogram. In the anteroposterior view, the lateral movement of the internal cerebral vein is, as is pointed out by JOHANSON in his Cases 22 and 23, less marked than that of the anterior cerebral arteries.

V. *Sellar and parasellar tumours.* The foramen of Monro is displaced only slightly upwards, and to an insignificant degree backwards, by craniopharyngiomas and pituitary and parasellar tumours. Like JOHANSON, we found that displacement of the cerebral veins indicates that the tumour is large. The basal vein, however, undergoes striking changes. It is stretched and more elevated at its point of origin than posteriorly; it is situated at a higher level over the sella turcica

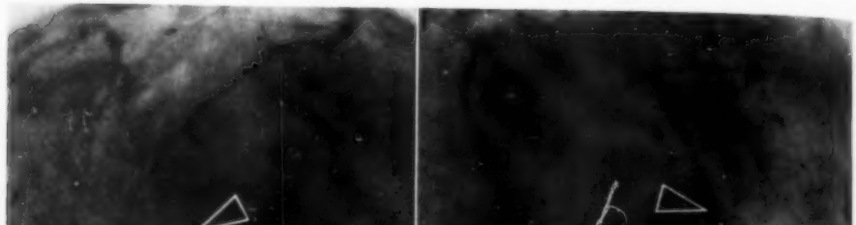

Fig. 8 (left). Tumour of corpus callosum. Whole internal cerebral vein displaced downwards; arc of great cerebral vein widened.

Fig. 9 (right). Thalamo-striate tumour. Considerable forward displacement of foramen of Monro. Angle formed by thalamo-striate and thalamo-trigonal veins and cerebral vein less acute than normal.

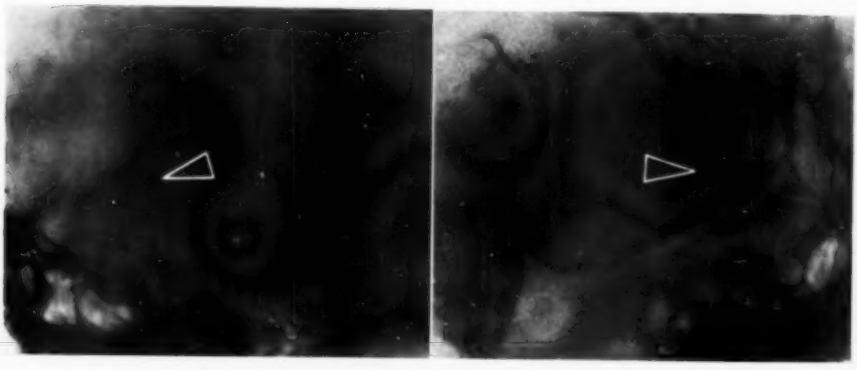

Fig. 10 (left). Thalamo-caudate tumour. Internal cerebral vein considerably stretched. Enormous upward displacement of venous angle (striate vein, cerebral vein, and vein of septum lucidum).

Fig. 11 (right). Temporal tumour invading basal ganglia. Basal vein of Rosenthal raised, dilated, and tortuous. Foramen of Monro and thalamo-striate vein displaced upwards.

(more than 1 cm) whilst in the antero-posterior phlebogram the anterior part of the vein is displaced to a point over 3 cm from the midline.

VI. *Temporal tumours.* The striate vein is elevated and the venous angle widened according to the size of the tumour, particularly if the tumour is situated posteriorly; the foramen of Monro is displaced upwards only if the thalamus is invaded or elevated by the tumour. The widening of the venous angle is the most interesting point. In one case of temporal tumour, a comparison between left and right lateral phlebograms was striking. The movement of the thalamo-striate vein is as important as is the displacement of the basal vein; this latter observation has been made by JOHANSON.

As is well known, the lateral displacement of the internal cerebral vein is considerable. In the antero-posterior view the insular vein is stretched and displaced medially and upwards.

VII. *Central expanding processes.* These include tumours of the basal ganglia, corpus callosum, and pineal body, and cause a considerable change in the usual pattern of the central veins, as JOHANSON pointed out in 1952.

Since 1937, EGAZ MONIZ has made a special study of pineal tumours, and in one of his papers (1953) he described an upward displacement of the great cerebral vein, the normal curve of which is inverted and thus becomes concave downwards. To a greater degree, the whole Galen system is deflected and stretched, forming a curved line, convex upwards, joining at its posterior end the inferior longitudinal sinus. The basal vein also is stretched more posteriorly, and near the straight sinus it is unusually convex downwards. In other cases, only the anterior part of the great cerebral vein is elongated and forms nearly a right angle with its posterior part (Fig. 4). When the pineal body is calcified, the distance between the calcification and the great cerebral vein is increased considerably (Fig. 5). Similar cases have been published by JOHANSON and ECKER.

Space-occupying lesions of the corpus callosum displace the internal cerebral vein basally, whilst there is little or no lateral movement. It should be borne in mind that hydrocephalus can accompany these tumours and thus increase the downward displacement of the internal cerebral vein. When the space-occupying lesion is in the anterior part of the corpus callosum and the septum lucidum, the venous angle is displaced directly backwards and slightly downwards (Fig. 6). In tumours situated in the central part of the corpus callosum, mainly the anterior part of the internal cerebral vein is depressed (Fig. 7). When the tumour invades the splenium, the normal arc of the great cerebral vein is considerably

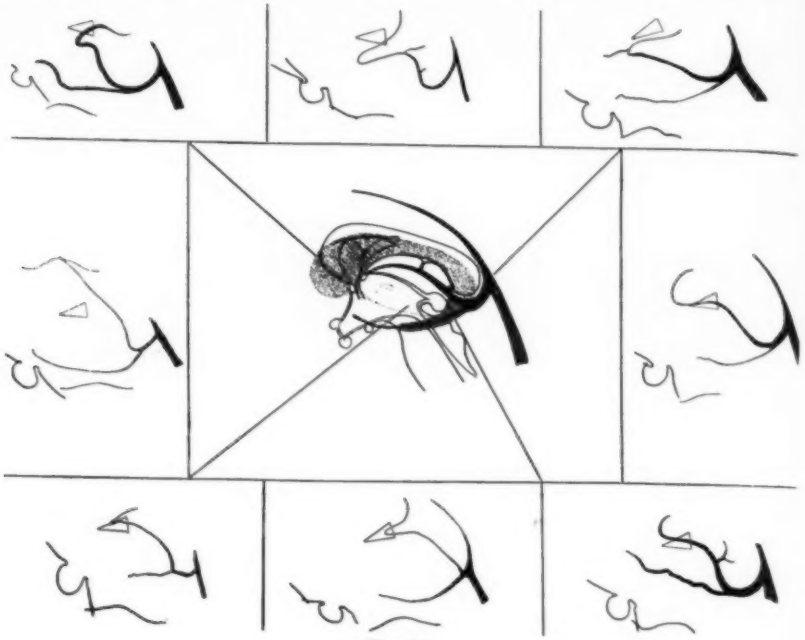

Fig. 12.

Top drawings: obtained from phlebogram tracings in tumour of corpus callosum. Foramen of Monro depressed and according to anterior or posterior situation of lesion displaced backwards or forwards.

Left: Thalamo-caudate tumour. Internal cerebral vein displaced upwards.

Right: Posterior thalamic tumour. Foramen of Monro displaced forwards and striate vein upwards.

Bottom: Left and middle drawing: deep phlebograms in two cases of pineal tumour. Right: basal vein tortuous and displaced upwards at point of origin. Int. cerebral vein and striate vein also displaced upwards. Appearances suggestive of deep-seated temporal tumour.

stretched (Fig. 8). Tumours of the third ventricle and the midline suprasellar tumours displace the venous angle markedly upwards and slightly backwards although there is no lateral displacement in the antero-posterior phlebogram. On the other hand, the thalamo-caudate tumours first elevate the thalamo-striate vein and then displace the internal cerebral vein upwards (Figs. 9 and 10). In the antero-posterior view, there is a definite lateral movement of the internal cerebral vein.

The signs of invasion of the thalamus, caudate nucleus, and corpus callosum, furnished by the phlebogram, associated with those established by arteriography, in cases of superficial tumours, enable one to determine

the impracticability of complete removal of the tumour, and are thus of great importance as regards prognosis. For example, in a case of temporal tumour the basal vein is elevated, enlarged, and tortuous, the striate vein is displaced upwards, and the venous angle wide, indicating infiltration of the basal ganglia (Fig. 11).

In Fig. 12, obtained from phlebogram tracings, the displacements of the deep veins in central tumours, are illustrated.

In conclusion, we would draw special attention to the usefulness of the tracing of the normal topogram which we have suggested. It has only to be superimposed on the appropriate films to establish at a glance the exact position of tumours in different parts of the cerebral hemisphere.

SUMMARY

The literature of the normal and abnormal appearances of the deep cerebral veins is reviewed and discussed. The normal topogram of the junction between the thalamo-striate vein and the internal cerebral vein is described and its value in assessing minimal deformities of the deep veins emphasized. Displacements of the deep veins in superficial and deep tumours are defined systematically.

ZUSAMMENFASSUNG

Die Literatur über das normale und pathologische Aussehen der tiefen Hirnvenen wird besprochen. Das normale Topogram des Angulus venosus wird beschrieben und dessen Wert für die Feststellung minimaler Deformitäten der tiefen Venen wird betont. Verschiebungen der tiefen Venen bei oberflächlich oder tief gelegenen Tumoren werden systematisch erklärt.

RÉSUMÉ

Les auteurs passent en revue et examinent la littérature concernant les aspects normaux et anormaux des veines cérébrales profondes. Ils décrivent le topogramme normal de l'angle veineux et insistent sur son intérêt pour apprécier de minimes déformations de veines profondes. Ils précisent systématiquement les déplacements des veines profondes dans les tumeurs superficielles et profondes.

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FROM THE ROENTGEN DEPARTMENT (DIRECTOR: PROF. ERIK LINDGREN),
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TENTORIAL HERNIATIONS

I. ANATOMY

by

N. Azambuja, E. Lindgren and *S. E. Sjögren*

An autopsy material of 100 cases of cerebral tumours from the years 1949 to 1953 has been studied in order to arrive at a better understanding of the anatomic basis for the roentgenologic changes which herniations may cause. Many authors have discussed brain herniations from anatomic, clinical, and therapeutic viewpoints, since the first observations were made by MEYER in 1920, but their roentgenologic appearance has scarcely ever been treated.

Cerebral herniations may be divided into four groups:

1. Occipital;
2. Tentorial, which may be either ascending or descending;
3. Sphenoidal ridge, also ascending or descending;
4. Lateral: below the falx.

Normal cases.

Fig. 1 (*left*). Cerebellum removed. The larger part of the tentorium remains, but the most anterior part has been cut off in order to show groove produced by its free edge in inferior part of hippocampal convolution.

Fig. 2 (*right*). Free parts of uncus of somewhat different size on the two sides.

Fig. 3. Anterior herniation on left side with displacement of posterior communicating artery.

In this paper, the macroscopic appearances of tentorial herniations will be treated only to an extent necessary for an understanding of the changes seen in roentgen examinations of the brain; a discussion of the different theories of the pathogenesis does not fall within the scope of this paper.

The intercrural cistern, the cerebral peduncles, the cistern of the vein of Galen — which we call the quadrigeminal cistern — the quadrigeminal plate, the ambient cistern surrounding the brain stem, and the lateral extensions of the ambient cistern, known as the wings, lie in the tentorial notch, in this order from front and backwards. The posterior cerebral artery and the basal vein are situated in the wings. The posterior communicating artery runs backwards from the internal carotid artery, passing the uncus of the hippocampus, towards the posterior cerebral artery. The ambient cistern communicates with the subarachnoid space above the cerebellum. The wings join above the third ventricle and the posterior part of the optic thalamus. The vein of Galen is situated in the centre of the quadrigeminal cistern. The roof of the cistern is formed by the splenium of the corpus callosum, the floor consisting of the quadrigeminal plate and the upper part of the vermis of the cerebellum. If a brain is examined from below with the tentorium still in position, the uncus is seen to protrude inwards, medially, to the free edge of the tentorium. If the tentorium is removed, a groove on the surface of the brain corresponds to its edge (Fig. 1). Discussions as to whether or not this is a normal condition are recorded in the literature. All our normal cases, however, have had this appearance. The part of the uncus situated medially to the free edge of the tentorium may vary somewhat in size on the two sides (Fig. 2).

In cases of descending tentorial herniations, a portion of the brain substance in the vicinity of the free edge of the tentorium is pressed downwards through the tentorial notch. It seems from our investigations that it is practical, at least from the viewpoint of roentgen diagnosis,

to differentiate between certain types of herniation, namely anterior, posterior, and complete; these in turn may be unilateral or bilateral. The most frequent types of descending herniation are the anterior.

A left-sided anterior herniation is shown in Fig. 3. The uncus of the hippocampus is oedematous, the normal groove becomes less clear or disappears completely, and a new groove appears more laterally on the hippocampal convolution. The uncus protrudes downwards, occupies a part of the intercrural cistern, and compresses the crural cistern. The posterior communicating artery is displaced. In order to differentiate between an unusually large, normal uncus, and a herniated one, these secondary phenomena are of decisive importance.

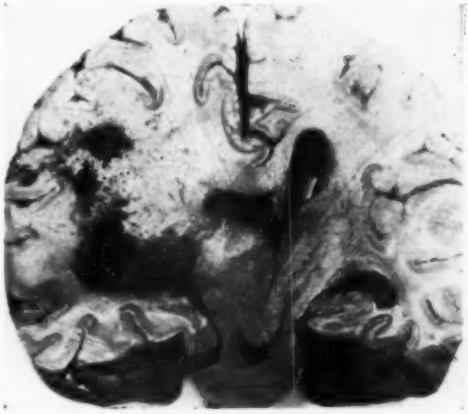


Fig. 4. Vertical section through a brain with right-sided herniation. Uncus overhangs edge of tentorium on right side. Left side normal. Deformation of brain stem.

Anterior herniations also deform the brain stem (Fig. 4). If they are bilateral, marked compression and displacement of the brain stem in a posterior direction may occur. The deformation of the brain stem is comparable to the effect of a basal tumour situated in the midline.

Figs. 5 and 6 show examples of posterior herniation. The convolutions mainly involved in such cases are the posterior part of the hippocampal convolution, the isthmus of the fornical gyrus, and the gyrus cinguli. The anterior part of the lingual gyrus may also be involved in cases of large herniations. The posterior herniations occupy the lateral part of the quadrigeminal cistern, displace the ambient cistern downwards, and increase the distance between the posterior part of the third ventricle and the upper part of the vermis. The vein of Galen is pushed laterally. The posterior herniations cause a different deformity of the brain stem from the anterior ones, *i. e.* a flattening of the posterior part. On the opposite side, the shape of the hemisphere is also influenced by the herniation. The uncus is often not visible from below when the tentorium remains in place.

The deformity inflicted on the brain stem in cases of bilateral anterior and posterior herniations depends on the individual sizes of the herniations (Fig. 7). When anterior and posterior herniations are so large that they

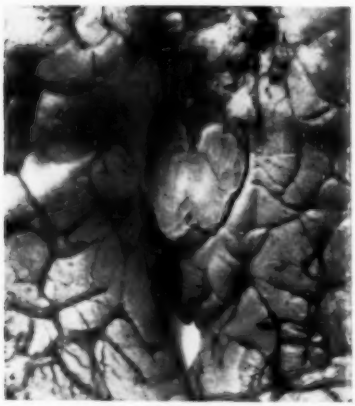


Fig. 5. Posterior herniation on left side.

join there is formed what we call a complete herniation. This is depicted in Figs. 8 and 9 from a case operated upon for a large glioma. The tumour was extirpated but the patient died five days later. The herniation had not been reduced in size. Complete herniations usually cause very considerable displacement of the brain stem towards the opposite side. In all cases with displacement of the brain stem the peduncle on the opposite side is compressed against the free edge of the tentorium. This causes a groove of varying depth.

Bilateral complete herniations seem to be rare. Such a horseshoe-shaped herniation is seen in Fig. 10. The two shanks of the horseshoe may be more or less thick, and the deformity of the brain stem may consequently present different appearances. Vessels to the inferior surface may be compressed between the free edge of the tentorium and the herniation.

Fig. 6. The pulvinar thalamus is pressed down and protrudes between herniation and brain stem; posterior herniation in a case of parietal glioma.

Expanding lesions in the posterior fossa may provoke ascending tentorial herniations. The result of a puncture of the lateral ventricles in order to decrease the intracranial pressure may be an increase in the herniation. An expanding lesion in or behind the vermis pushes the brain stem forwards and upwards. This may produce a displacement of the posterior part of the third ventricle upwards. Roughly speaking, an ascending herniation is central, but may predominate on one side. In such a case the herniation is formed not only by the upper part of the vermis but also by a portion of a cerebellar hemisphere. The ambient cisterns and their vessels are in such cases more displaced on one side than on the other. In cases with a large

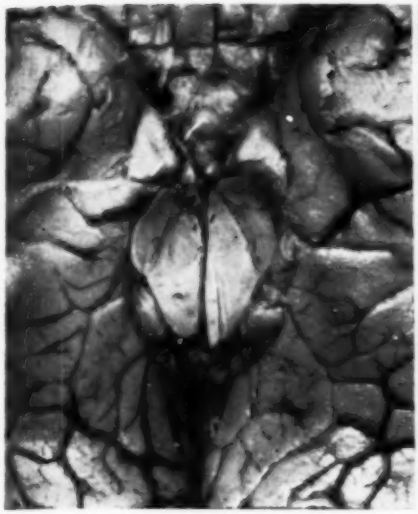


Fig. 7. Bilateral anterior and posterior herniations. Crural cisterns compressed on both sides, mostly on the left. Posterior part of the brain stem compressed on both sides, a little more on the right side.

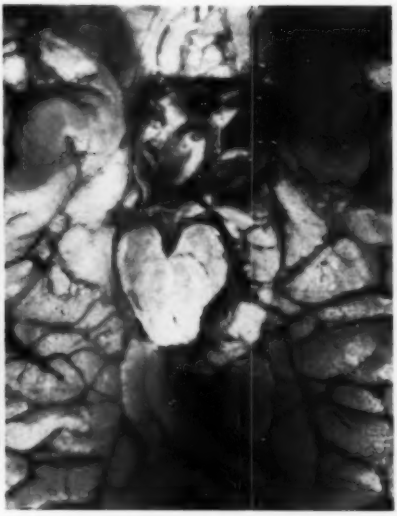


Fig. 8. Complete herniation of all medial parts of hippocampal convolution plus anterior part of lingual convolution and fornical gyrus on left side.

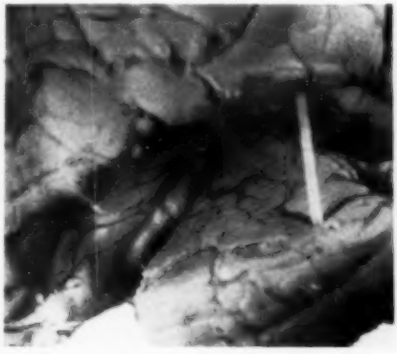


Fig. 9. Same case as Fig. 8. Brain seen from behind and below; cerebral hemisphere and cerebellum separated to show the herniation. Groove limiting the herniation laterally is clearly seen.

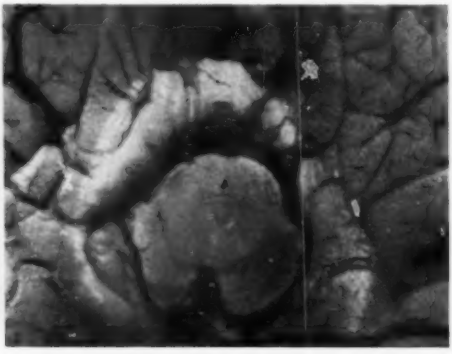


Fig. 10. Bilateral complete herniation or horseshoe herniation; compressed vessels.

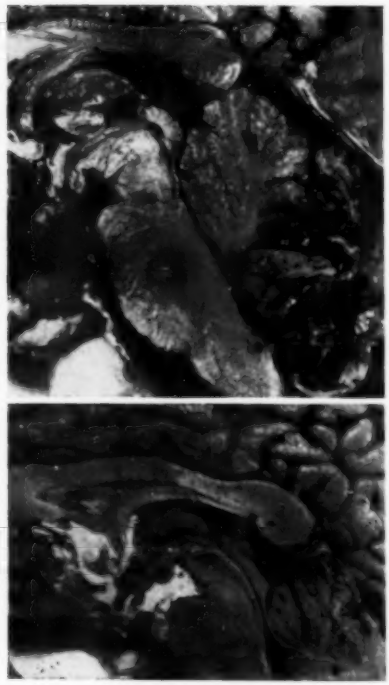


Fig. 11. Upward tentorial herniation with compression of quadrigeminal cistern (*top*). Normal case for comparison (*below*).

herniation upwards the vermis may come into contact with the splenium of the corpus callosum (Fig. 11).

Expanding lesions resulting in considerable dilatation of the fourth ventricle may give rise to herniation of such a high degree that the upper part of the ventricle may be herniated.

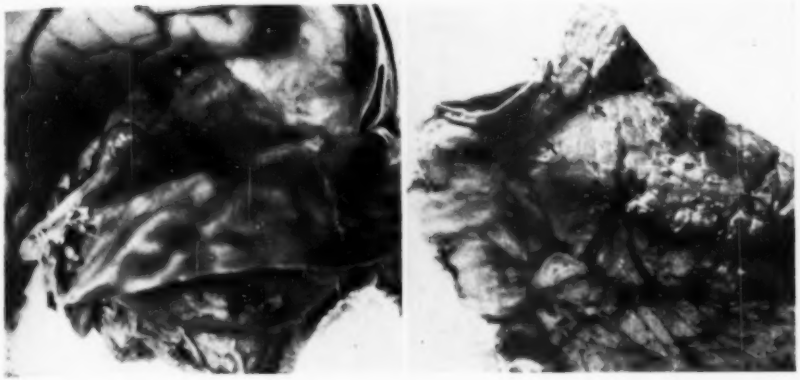
A representation of the autopsy material of the 100 cases of brain tumour is given in the table below. Of the total number of occipital herniations, 52 were produced by supratentorial tumours and 17 by infratentorial. Of the tentorial herniations, 63 were produced by supratentorial tumours, and 15 by infratentorial. There were 19 bilateral herniations, all produced by supratentorial tumours. The total number of tentorial herniations is thus higher than the occipital ones, and these herniations predominate also in cases of supratentorial tumours. On the other hand, infratentorial tumours produce slightly more occipital than tentorial herniations.

Diagram 1 may be said to constitute a summary of our investigations. Tumours of the brain stem are not included in this study since they fill the tentorial notch, through which there consequently can be no herniation. The diagram shows that anterior herniations predominate over other groups. Furthermore, most of the bilateral herniations are mainly anterior. Complete herniations are also frequent. Posterior herniations alone are not common; they are mostly associated with central and pituitary tumours.

Conclusions

In most cases of supratentorial tumours, an anterior herniation is the first to be produced. In some cases — probably mainly in central tumours — one anterior and one posterior herniation may be produced at the same time and, as they grow larger, join to form a complete herniation.

Bilateral herniations are mainly produced by central tumours, and, in this material, never by temporal tumours. Generally, infratentorial



Cerebellar tumour.

Fig. 12 (*left*). The tentorium undisturbed to show herniated upper part of cerebellum.
Fig. 13 (*right*). Tentorium removed to show the groove produced in cerebellum by free edge of tentorium.

Table

Frequency of different types of herniations in this material

TUMOURS		HERNIATIONS					
Location	Number of Cases	Occip.	Tent.	Ant.	Post.	Compl.	Bilat.
Frontal	21	14	17	7	2	8	7
Parietal	15	9	13	9	1	3	2
Occipital	2	2	2	1	0	1	1
Temporal	16	10	15	9	0	6	0
Central	16	10	11	5	4	2	6
Pituitary	9	7	5	2	2	1	2
Cerebellar	7	6	6				
Cerebellopontine	7	7	5				
Pontine	2	2	1				
IV ventricle	5	2	3				
Total	100	69	78	33	9	21	18

tumours produce both tentorial and occipital herniations, but a few produce only one or the other type. In only two cases of very small tumours was there no herniation at all.

We feel that the division of tentorial herniations into four different types, three downwards and one upwards, may be useful for radiologic diagnosis with due regard to the fact that these types produce different changes in the brain stem and in surrounding anatomic structures.

This material is small but shows the high frequency of tentorial herniations, and their predominance over occipital herniations.

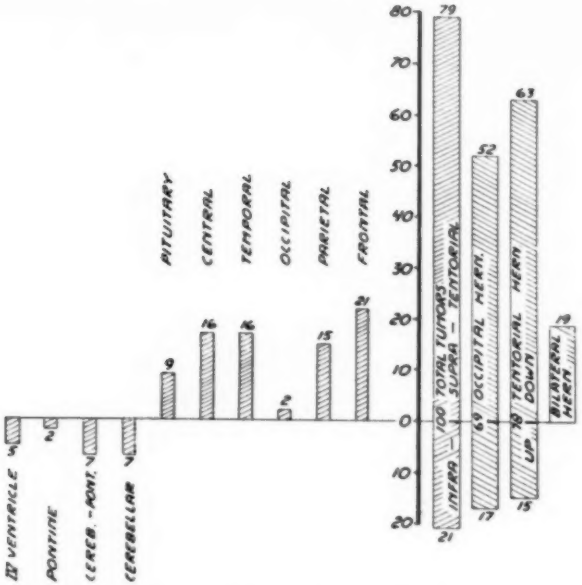


Diagram 1. Diagrammatic representation of the autopsy material. The horizontal line separates supra- and infratentorial tumours and related herniations.

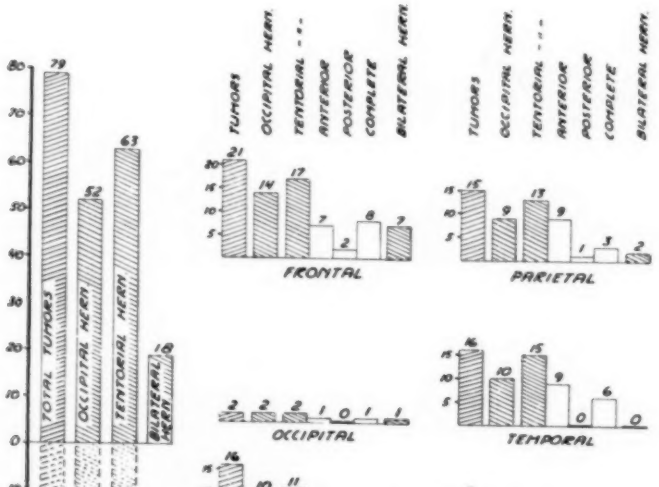


Diagram 2. Supratentorial tumours and corresponding herniations classified in different types.

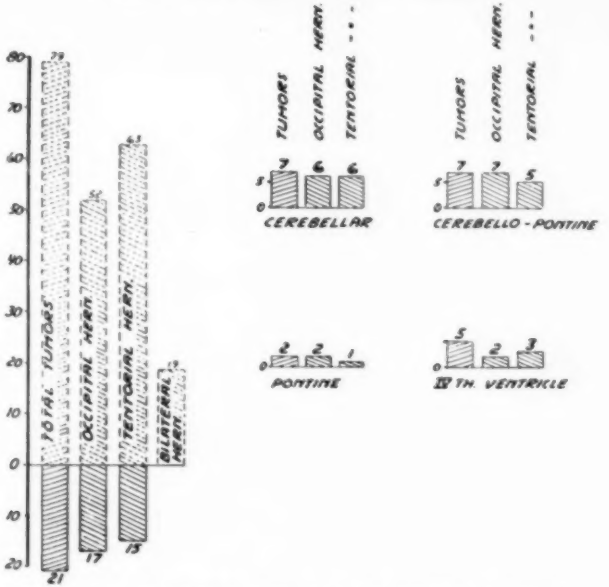


Diagram 3. Herniations caused by infratentorial tumours.

SUMMARY

An autopsy material of 100 cases of brain tumour have been studied with special reference to cerebral herniations. The patho-anatomy, the mechanism, and the macroscopic appearances of tentorial herniations, which form one of the suggested groups of cerebral herniations, are described and illustrated by the material. The common occurrence of tentorial herniations, and their predominance over occipital herniations, is shown by the investigation.

ZUSAMMENFASSUNG

Die Sektionsbefunde von 100 Fällen mit Hirntumoren sind, unter besonderer Berücksichtigung der Massenverschiebungen des Gehirns, studiert worden. Die Anatomie, der Mechanismus und das makroskopische Aussehen der Massenverschiebungen durch die Incisura tentorii, welche eine Gruppe der Massenverschiebungen bildet, werden beschrieben und mit Hilfe des Materiales illustriert. Das häufige Vorkommen dieser Verschiebungen und ihre Prädominanz über diejenigen durch das Foramen magnum wird durch die Untersuchung aufgezeigt.

RÉSUMÉ

L'autopsie de 100 cas de tumeurs cérébrales a été faite en vue d'étudier particulièrement les hernies cérébrales. L'anatomie pathologique, le mécanisme et les aspects macroscopiques des hernies tentorielles, qui constituent un des groupes proposés de hernies cérébrales, sont décrits et illustrés par le matériel des auteurs. Ce travail montre la fréquence des hernies tentorielles et leur prédominance sur les hernies occipitales.

(For References, see Part III.)

FROM THE ROENTGEN DEPARTMENT (DIRECTOR: PROF. ERIK LINDGREN),
SERAFIMERLASARETTET, STOCKHOLM, SWEDEN

TENTORIAL HERNIATIONS

II. PNEUMOGRAPHY

by

N. Azambuja, E. Lindgren and *S. E. Sjögren*

This is part of a series of studies of which LILIEQUIST's paper on the normal appearance of the cisterns represents a previous stage. Practically nothing has appeared in the literature about the possibilities of demonstrating tentorial herniations by means of pneumography, probably due to the fact that in most centres encephalography still has not replaced ventriculography in the diagnosis of most intracranial tumours. In order to determine whether a herniation is present or not, an examination of the cisterns, *i. e.* by encephalography, is as a rule necessary. PERRYMAN and PENDERGRASS have described herniation in the tentorial notch of the lateral ventricles and the third ventricle, a herniation that was observed in certain cases of very considerable dilatation of these ventricles. Such a dilatation has, in Sweden at least, only been observed in cases of stenosis of the aqueduct not due to tumour, and it may be regarded as a form of downward tentorial herniation. The upward displacement of the posterior part of the third ventricle, which is caused by many kinds of tumour in the posterior fossa, represents a type of upward herniation that has long been known. The third ventricle is, as it were, tilted forwards on its nose. This is generally not termed an upward herniation of the brain stem but, as a matter of fact, this is exactly what it is.

With the exception just mentioned an examination of the ambient, quadrigeminal, intercrural, and crural cisterns is required to determine if a downward tentorial herniation (a temporal pressure cone) is present. As pointed out in the first part of this study a posterior herniation causes deformation of the brain stem. The side on which the posterior herniation is situated becomes flattened, and the brain stem displaced towards the opposite side. The colliculate body on the ipsilateral side will thus be lower than on the contralateral side (Fig. 1). The statement by SPATZ

and HASENJÄGER that the colliculate body is higher on the side of the herniation, and that the brain stem on this side is often wider than on the contralateral, is not always true. It applied, generally, however, in cases of anterior herniations (Fig. 2). When anterior and posterior herniations are present simultaneously, the appearance of the brain stem depends on which of them is the larger. Fig. 3 is from a case with a large temporoparietal expanding lesion. The half-axial p. a. view shows the asymmetric brain stem, surrounded by the ambient cisterns. The brain stem is flattened in its upper posterior part and displaced to the right. The colliculate body is lower on the left than on the right side. The deformation is thus of the type caused by a posterior herniation.

Fig. 1. Vertical section through brain with left-sided posterior tentorial herniation. Left side of brain stem flattened and colliculate body on same side displaced downwards.

In the lateral view, the wing of the ambient cistern on the contralateral side crosses the upper part of the quadrigeminal plate, which is normal. On the diseased side, the cistern is compressed, displaced backwards and downwards, and projected over the lower half of the quadrigeminal plate. When a posterior herniation is large it flattens also the anterior surface of the cerebellum, the surface forming the posteroinferior boundary of the quadrigeminal cistern. Then the air above the cerebellum, which in most cases describes a smooth curve, becomes angular. Fig. 4 is from a case with anterior as well as posterior herniations. The intercrural cistern is only partially filled with air. The ambient cistern is displaced downwards with the wing projected over the lower half of the quadrigeminal plate, and the anterior surface of the cerebellum is flattened. In the half-axial p. a. view the brain stem is seen to have almost the same shape as in the former case. The deformity of the brain stem must therefore be due mainly to the posterior herniation, which is the larger one.

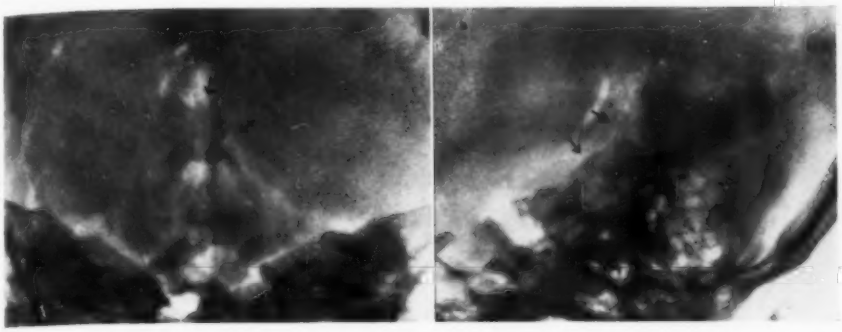
The appearance of an anterior herniation alone is shown in Fig. 5.

Fig. 2. Anterior tentorial herniation on left side (arrows). Colliculate body on same side displaced upwards and left side of brain stem wider than right.

The anterior and middle parts of the wing are pushed downwards on one side, but the posterior part crosses the upper part of the quadrigeminal plate. Thus, its position in relation to the quadrigeminal plate is normal. The p. a. view has been projected so that the intercrural and the crural cisterns are demonstrated. On the left side the crural cistern has a normal appearance, but it is compressed on the right side. Below the cistern, a soft tissue mass representing the herniation bulges into the lateral part of the intercrural cistern. Fig. 6 is a half-axial p. a. view from a case of a tumour in the postero-superior part of the frontal lobe, showing the deformity of the brain stem in this projection when there is an anterior herniation. The right part of the brain stem is wider than the left, and the right colliculate body is higher than on the left side.

Anterior and posterior herniations counteract each other and the deformity of the brain stem will then be more complicated. The case shown in Fig. 7 has a large temporal tumour on the right side, which has caused tentorial herniations on the same side. The brain stem is asymmetrical; it is flattened on the right side in its postero-superior part, and displaced to the left, as in a case of a posterior herniation. The colliculate body on the same side, however, is not displaced downwards but is higher than on the contralateral side, due to the fact that there is also an anterior herniation. What makes these appearances different from those of a single anterior herniation is the fact that in this case the posterior upper part of the brain stem is compressed in such a manner that it is narrower on the side of the herniation, instead of the other way around.

Another example of multiple herniations is shown in Fig. 8. The wing on one side is displaced in such a manner that it is evident that there is a posterior herniation. From the half-axial view it is seen that the brain stem is flattened on the left side, on which side the posterior herniation is situated. In addition, the intercrural cistern is completely compressed



a b

Fig. 3. Left-sided posterior herniation at pneumography.
a) Half-axial p. a. view (cf. fig. 1). Displaced colliculate body (↓). Flattening of brain stem (→).
b) Lateral view. Displaced wing of ambient cistern (→).

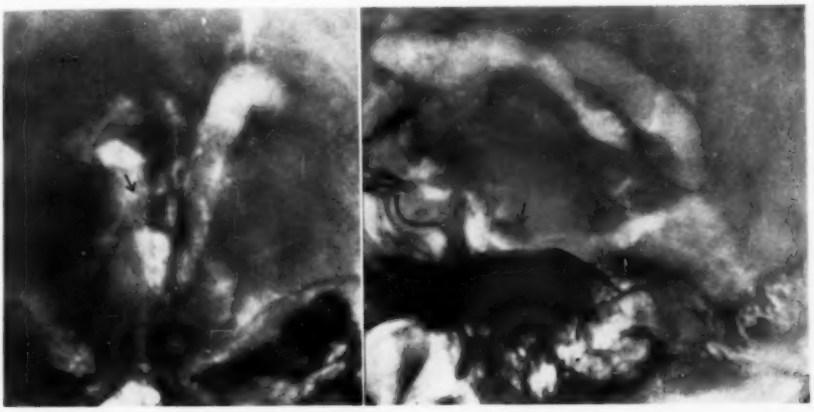


Fig. 4. Anterior and posterior herniations. Deformity of brain stem in half-axial view mainly due to posterior herniation.

and the basilar artery displaced against the clivus. In our experience this is a sign of bilateral anterior herniations. The deformity of the brain stem, as seen in the half-axial view, is slight in spite of the rather large posterior herniation evident in the lateral view. This is due to the counteraction of the anterior herniations.

In individual cases, the deformations caused by the herniations may cause difficulties when it comes to the localization of an expanding le-

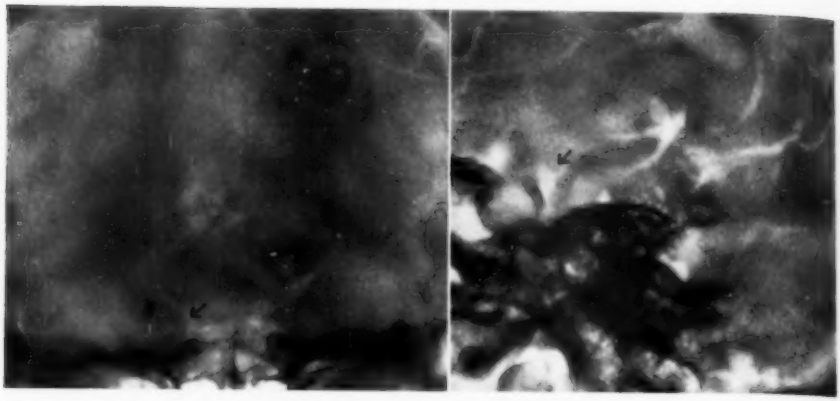


Fig. 5. Anterior tentorial herniation on right side bulging into lateral part of intercrural cistern (↙) and compressing crural cistern (↘).

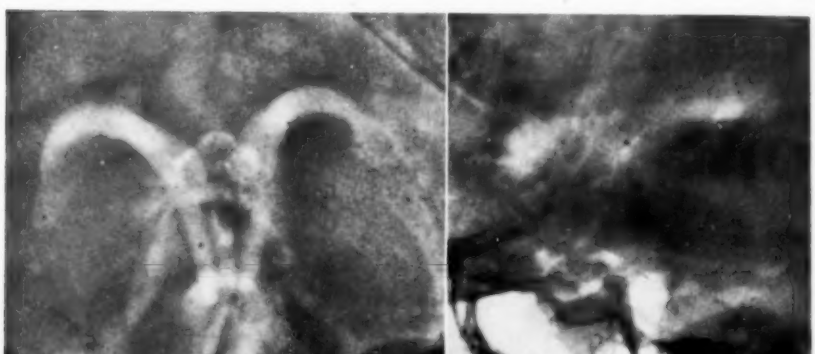


Fig. 6. Anterior tentorial herniation on right side. The half-axial p. a. view shows deformity of brain stem which is wider on right side. Colliculate body higher on the same side (cf. fig. 2).

sion. Large anterior herniations may displace the brain stem backwards, and consequently also the aqueduct; (cf. fig. 9, which represents a case with bilateral subdural haematomata; these were removed by operation and the patient, who had been deeply comatous, recovered and is now working as a nurse).

Fig. 7. Half-axial p. a. view in a case with anterior and posterior herniations on same side. Displacement of posterior upper part of brain stem to the left is due to posterior herniation; colliculate body not displaced downwards, due to pressure from the anterior herniation.

Fig. 8. Bilateral anterior herniations with complete compression of intercrural cistern (↓) and displacement of basilar artery (↙). Left-sided posterior herniation.

The upward herniations are perhaps of less importance from a practical point of view. The appearance of the third ventricle has already been mentioned. If the ambient cisterns fill, and there is air around the superior aspect of the cerebellum, these parts of the subarachnoidal space are displaced forwards and upwards. The quadrigeminal plate is kinked, and the lower part is displaced anteriorly (Fig. 10). The antero-superior surface of the cerebellum may press against the splenium so that this makes an impression in the former.

In cases with tumour situated below the fourth ventricle, causing a dilatation of its upper part, the possibility of demonstrating an upward herniation is good. At the lower edge of the quadrigeminal plate there is normally, in many cases, a small angular bulge. In cases of upward herniation this is enlarged and usually more rounded. This, in our opinion, is a sign that part of the cerebellum is herniated upwards. The indentation seen below the bulge is due to pressure from the edge of the tentorium.

Judging by our present experiences, pneumography offers good possibility for demonstrating downward tentorial herniations, while it is not quite so promising, generally speaking, for demonstrating upward herniations. The opposite is true when it comes to arteriography. Probably, the frequency of herniations would be greater in an autopsy material than in a clinical series, due to a great many factors, the most im-

Fig. 9. Bilateral anterior herniations with complete compression of intercrural cistern (⌐). Aqueduct displaced (↔) backwards; it runs practically straight upwards.

portant perhaps being that patients with large herniations more frequently die. Furthermore, our methods of investigation seem satisfactory for demonstrating large herniations in living patients, but smaller herniations may escape demonstration. The following figures from a consecutive series of 50 encephalographic examinations of supratentorial brain tumours with different localization and size may be of some value as they indicate the frequency in a clinical unselected material: herniations in 23 cases, none in 16, uncertain in 3, and, finally, unsatisfactory examination in 2 cases.

a b

Fig. 10. Tentorial herniation upwards. a) Encephalography. The quadrigeminal plate kinked and its lower part displaced anteriorly (⌐). b) Anatomical specimen. (Another case for comparison.)

SUMMARY

The encephalographic changes caused by tentorial herniations are described. The brain stem is asymmetric; the anterior herniations deform the crural and/or the intercrural cisterns; the posterior herniations displace the wing of the ambient cistern and may possibly deform the anterior surface of the cerebellum.

RÉSUMÉ

Les auteurs décrivent les modifications encéphalographiques causées par les herniations tentorielles. Le tronc cérébral est asymétrique; les hernies antérieures déforment les citernes crurales et/ou intercrurales; les hernies postérieures déplacent l'aile de la citerne ambiante et peuvent éventuellement déformer la face antérieure du cervelet.

ZUSAMMENFASSUNG

Die encephalographischen Veränderungen, welche durch Massenverschiebungen des Gehirns durch die Incisura tentorii verursacht sind, werden beschrieben. Der Hirnstamm ist unsymmetrisch. Die vorderen Verschiebungen deformieren die cruralen und beziehungsweise oder die intercruralen Cisternen. Die hinteren Verschiebungen verlagern den Flügel der Cisterna ambiens und können eventuell die vordere Oberfläche des Cerebellums deformieren.

(For References, see Part III.)

FROM THE ROENTGEN DEPARTMENT (DIRECTOR: PROF. ERIK LINDGREN),
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TENTORIAL HERNIATIONS

III. ANGIOGRAPHY

by

N. Azambuja, E. Lindgren and *S. E. Sjögren*

The cisterns around the brain stem and above the sella turcica contain numerous arteries and veins. The chances of one or more vessels being displaced or compressed are therefore considerable when herniated portions of the brain bulge into, and more or less fill one or more of these cisterns.

The vascular changes caused by herniations have received more attention in the literature than the alterations produced in the encephalographic appearances. The consequences of an arterial compression have been discussed both from a clinical and pathologic viewpoint, *e. g.* by ETHELBERG and JENSON and by MEYER, respectively. The latter has demonstrated that haemorrhagic infarctions may arise in the supply area of an artery compressed in the tentorial notch in cases with herniations. References to the displacement of the vessels were first made in the pathology literature but especially in recent years they have also appeared in contributions to neuroradiology. The angiographic changes have as a rule been presented with reference to individual vessels or single cases. It appears from these papers that it is often possible to diagnose and localize tentorial herniations by means of angiography.

The following vessels are of roentgenologic interest in this connection: the anterior choroidal, the posterior communicating, the basilar, the posterior cerebral, and the superior posterior cerebellar arteries with their main branches, the basal veins, and the great vein of Galen.

Anterior down-herniations displace the posterior cerebral artery and the posterior communicating artery in the manner shown in Fig. 1. The former is depressed in its anterior part, while the latter has changed direction and runs more downwards than normal. In a. p. views one observes that the posterior cerebral artery, and sometimes the posterior communicating artery as well, are displaced medially in varying degrees.

In posterior herniations it is the posterior part of the posterior cerebral

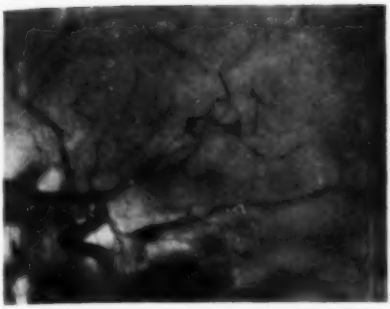

Fig. 1.

Fig. 1. Anterior tentorial down-herniation. Posterior cerebral artery depressed, and posterior communicating artery directed basally.

Fig. 2. Posterior tentorial down-herniation. Posterior part of posterior cerebral artery flattened and displaced medially.

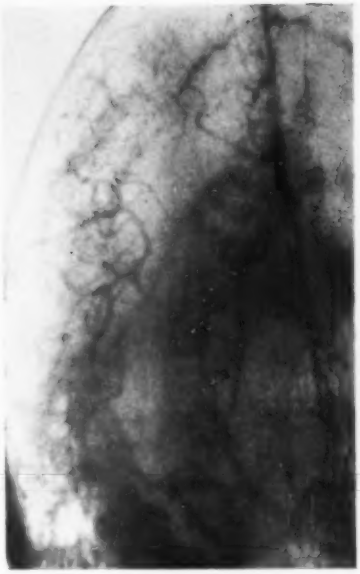

Fig. 2.

artery which is displaced medially (Fig. 2). In the phlebogram one may observe a similar displacement of the posterior part of the basal vein. This vein is more easily affected by posterior than anterior herniations, due to its anterior part being above the uncus.

If a herniation is complete, it depresses the posterior cerebral artery along the entire length of the tentorial notch (Fig. 3). The occipital and temporal branches, in order to reach the supratentorial region, must first circumvent the herniation, and when passing the edge of the tentorium they form sharp and sometimes acute angles. Such deformations are typical. The a. p. film shows considerable medial displacement of the vessels, indicating displacement of the brain stem.

Anterior herniations, large enough to fill the intercrural cistern, depress the basilar artery which therefore becomes accordion-shaped. This change may usually be observed on encephalography. It is, of course, easily seen on vertebral angiography.

Fig. 4 is from a case with bilateral subdural haematomas. The shape of the brain stem is very exactly shown in the half-axial a. p. view since the vessels cling to it like a stocking. The colliculate bodies are clearly outlined; the left is lower and the brain stem depressed due to the presence of a posterior herniation on that side, in addition to the anterior her-

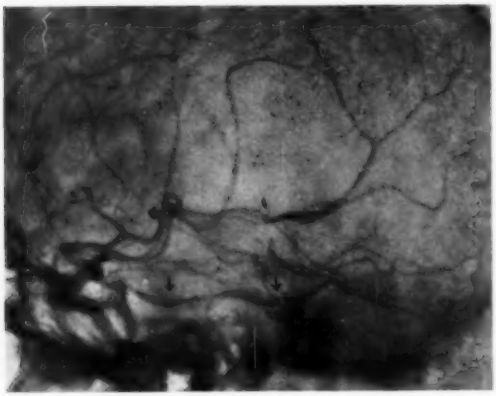

Fig. 3. Complete down-herniation. Whole of posterior cerebral artery pressed down. Its temporal branches are deformed in circumventing the herniation.

niations. In such a case, the shape of the brain stem may be determined equally easily by angiography as by encephalography. If carotid angiography has been performed, filling of the posterior cerebral artery is a necessary prerequisite. Only considerable changes can be demonstrated by unilateral investigations. But if bilateral carotid angiography has been carried out, the shape and position of the brain stem can more easily be determined by comparison of the two sides, *e. g.* by superimposing tracings of the half-axial a. p. films.

An exact outline of the brain stem is obtained by encephalography. This is not possible in angiography, particularly if only the main vessels are filled, but a rough idea of its shape may be gained. The anterior part is best outlined by the posterior cerebral arteries; however, a possible source of error is the fact that the arteries are not always on the same level on both sides in the crural cistern. If the beam direction is oblique to the plane of the cistern, the brain stem may seem asymmetric without being so. The posterior part is best outlined by the basal veins, since the posterior cerebral artery not seldom forms a loop directed laterally outwards into the wing of the ambient cistern.

In judging minor changes in lateral films, a possibility of comparing the two sides is also of great assistance; by comparison with the opposite normal side, the small anterior herniation on the right side of the case shown in Fig. 5 becomes apparent. The presence of a posterior herniation on the same side in the same case is more easily seen in the venous phase (Fig. 6). The displacement of the basal vein on the right side is easier to observe by comparison with the normal side. The basal and medial displacement of the basal vein is important, since the posterior cerebral artery, when it does not fill in carotid angiography, is the only sign of a posterior herniation.

Anterior herniations can under the same circumstances only be demonstrated by observation of the anterior choroidal artery. The cisternal part of this artery lies close to the medial surface of the uncus. In a half-axial a. p. view it runs in a curve with a medial convexity around

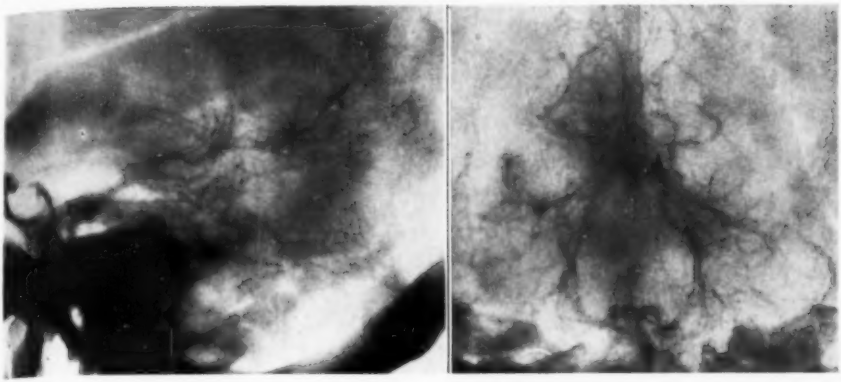

Fig. 4. Large bilateral anterior down-herniations. Basilar artery depressed and accordion-shaped. The half-axial a. p. view shows brain stem outlined by vessels. Left colliculate body (↓) lower than the right. This deformation is caused by a posterior herniation on the left side.

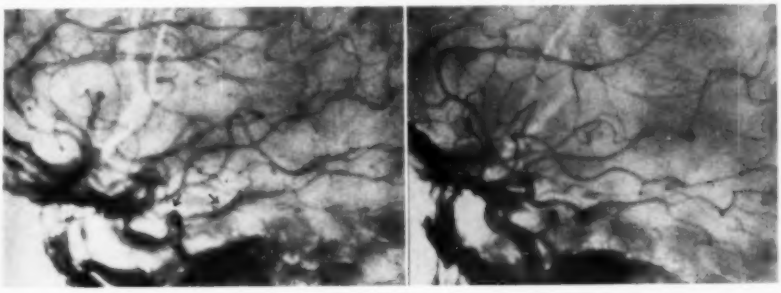

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Fig. 5. The presence of an anterior down-herniation on right side (a) becomes apparent from comparison with normal left side (b).

the uncus and through the crural cistern out to the temporal horn. In lateral films it usually has a curved course from its origin to the level of the knee of the temporal horn. Due to its intimate relation with the uncus, it is easily affected by an anterior down-herniation. In cases of large herniations, the medial displacement is obvious, and the vessel may be dislocated to or above the midline. In smaller herniations it may often be difficult by unilateral carotid angiography to determine whether the vessel is displaced medially or not. When the anterior part of the hippocampal gyrus is displaced medially and, so to speak, rolls

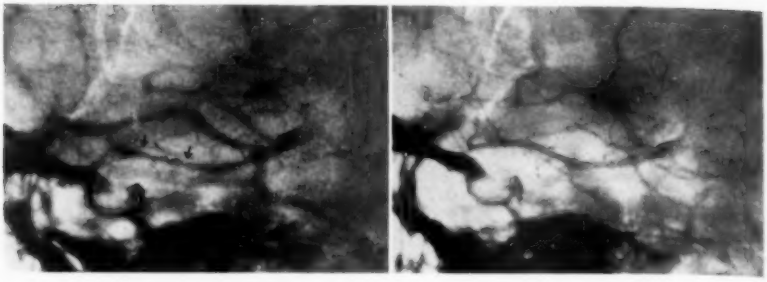

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Fig. 6. Same case as in fig. 5. On right side (a), the middle and posterior parts of basal vein are pushed down, indicating the presence also of a posterior herniation; b) normal left side.

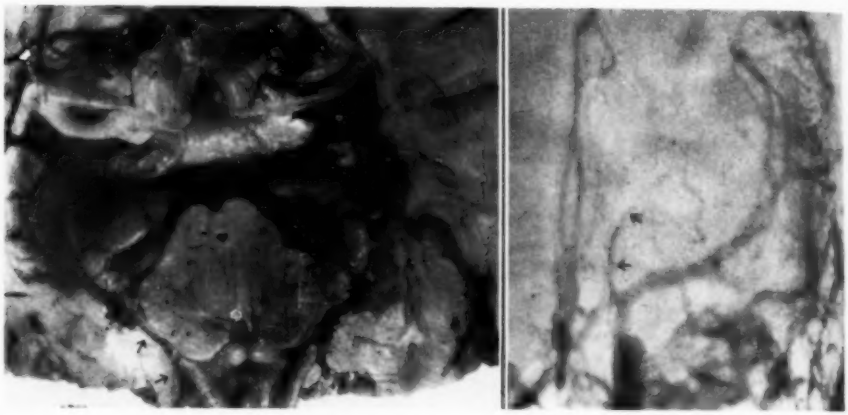

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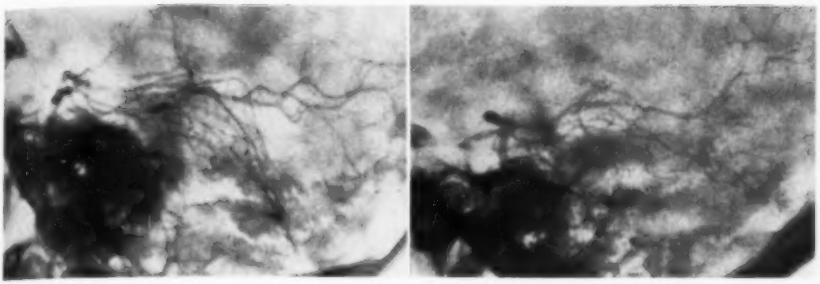
Fig. 7. a) Photograph from above of brain divided by a horizontal section through temporal horns. On the left side, the anterior choroidal artery describes a normal curve around the uncus; on the right, there is herniation of the anterior part of the hippocampal gyrus, and the anterior choroidal artery circumvents both the uncus and the herniation, thus describing a longer curve before reaching the temporal horn. b) Half-axial view in a case with anterior down-herniation. Anterior choroidal artery not displaced so much medially, but it runs a longer arc than is normal.

over the edge of the tentorium, this means that the anterior choroidal artery must circumvent not only the uncus, but also the herniated part of the hippocampus (Fig. 7). This change in the course of the artery, meaning that the cisternal part must describe a longer than normal curve



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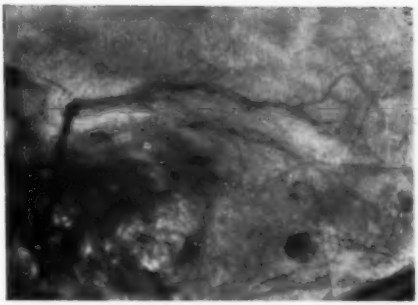

c

Fig. 8.

a) Posterior up-herniation. One of the superior cerebellar arteries is more displaced than the other. The herniation is therefore asymmetric.
b) Unilateral up-herniation farther forwards in the notch. The tumour was situated in cerebello-pontine angle.
c) Bilateral up-herniation. All four arteries are displaced upwards to same degree (angioreticuloma).

with a medial convexity, may often be demonstrated in half-axial a. p. views, even in cases where the medial displacement is not great enough to be definitely pathological

In judging this change, the projection of the vessel must be carefully taken into account. The length of the arc appearing in the film is a function of the beam direction and the angle between the object and the plane of the film. In lateral films, the vessel as a rule appears stretched and often somewhat depressed; in our material other shapes, such as an arc, for instance, are very rare.

Up-herniations through the tentorial notch may be of various types. A more or less symmetric, not seldom horseshoe-shaped herniation of the upper part of the vermis seems to be the most common. In other cases the herniation is unilateral, comprising the upper surface of the hemisphere. As a rule it extends to the posterior edge of the notch, while its forward extension varies. In rare cases the entire contents of the posterior fossa bulge upwards.

The appearances in lateral films of three different types of up-herniations are seen in Figs. 8—10.

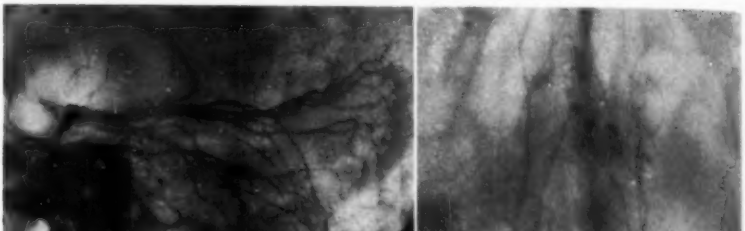

Fig. 9. Symmetric, posterior up-herniation. The two posterior cerebral arteries are pushed apart.

A large posterior up-herniation, mainly symmetric and of typical appearance, is shown in Fig. 9. The branches of the superior cerebellar arteries above the vermis are pushed upwards to the level of the great vein of Galen, which is flattened from below by the displaced vermis. The deformation of the arcs of the medial posterior choroidal arteries seen in lateral views is common in this type of up-herniations; the same is true of the separation of the two posterior cerebral arteries through lateral displacement on both sides at the posterior part of the tentorial notch.

In the case shown in Fig. 10, the up-herniation extends more forwards than in the previous case, which is evident from the position of the arc of the superior cerebellar artery above the posterior cerebral artery. The vein of Galen is somewhat flattened in this case as well, but the change is situated farther forward and extends forwards on to the basal vein, the posterior part of which is displaced upwards in a curve.

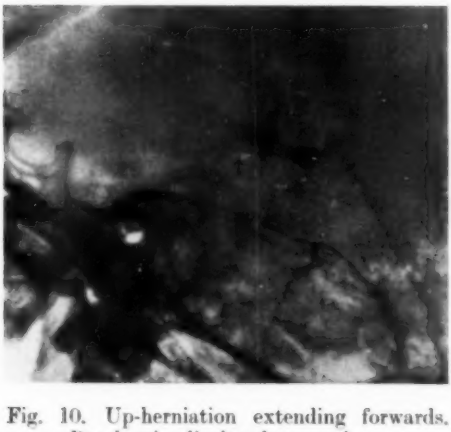

Fig. 10. Up-herniation extending forwards. Basal vein displaced upwards.

It seems that an up-herniation of the vermis can really compress the vein of Galen against the splenium, and it is probable that in most cases a more or less complete compression of this type is the true explanation of the so-called thrombosis of the great vein of Galen.

If carotid angiography has been performed in a case with a tumour in the posterior fossa, changes of the veins like the ones shown in the last two instances may be the only signs indicating the presence of an up-herniation.

In cases with unilateral up-herniation of a part of the cerebellar hemisphere, only one of the superior cerebellar arteries is elevated but often also the posterior cerebral artery on the same side. It causes an asymmetric deformation of the brain stem in a. p. films.

Herniations are of course not the primary object of cerebral angiography. Mapping out herniations as far as angiography permits would in many cases require angiography in more than one artery, sometimes in both carotid arteries as well as the vertebral artery. However, even without such supplementary investigations, the possibilities of demonstrating the presence of tentorial herniations angiographically seem to be good, and this is particularly true of up-herniations when vertebral angiography is carried out.

SUMMARY

The vascular changes occurring in individual vessels, and their significance in the localization and diagnosis of tentorial herniations, are discussed. Angiography appears to offer reasonable possibilities of demonstrating herniations; this is particularly true in cases of up-herniations examined by vertebral angiography.

ZUSAMMENFASSUNG

Es werden sowohl die bei Massenverschiebungen des Gehirns durch die Incisura tentorii auftretenden Lageveränderungen der Gefässe, als auch ihre Bedeutung für die Lokalisation und Diagnostik derselben diskutiert. Die Angiographie scheint recht gute Möglichkeiten zu bieten Massenverschiebungen zu demonstrieren. Dies gilt besonders für Fälle mit Verschiebungen nach oben, untersucht mittels Vertebralisangiographie.

RÉSUMÉ

Les auteurs étudient les modifications vasculaires qui touchent certains vaisseaux, et leur intérêt pour la localisation et le diagnostic des hernies tentorielles. L'angiographie paraît offrir des possibilités réelles pour mettre en évidence des hernies; ceci est particulièrement vrai dans les cas de hernies vers le haut examinés par angiographie vertébrale.

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FROM THE MANCHESTER ROYAL INFIRMARY AND THE UNIVERSITY OF MANCHESTER, MANCHESTER, ENGLAND

CLINICO-PATHOLOGICAL ASPECTS OF PRESSURE CHANGES AT THE TENTORIUM

by

R. T. Johnson and *P. O. Yates*

Increasing intracranial pressure and the expansion of local lesions in the cranial cavity produce secondary changes in the central nervous system of infinite variety. Herniation into the incisura tentorii first illustrated by MEYER in 1920, is now recognised as a dangerous complication of raised pressure, but its effects are by no means uniform; several factors play their part in determining the pattern and degree of pathological change and its associated clinical manifestations, notably the site of a tumour, whether it has produced surrounding oedema, whether that oedema has spread into the mid brain (Fig. 3), but most important of all, the speed at which herniation develops. Where the increase of pressure is catastrophic as in the massive intracerebral haemorrhages, complete disorganisation of the mid brain with extensive haemorrhages may result, and although this is invariably fatal, it may not be so immediately (Fig. 1). The accompanying deep coma, rigidities, dilated fixed pupils and changes in vital functions are familiar (VINCENT and his colleagues 1936). Sometimes however the rise of pressure is slowly progressive, as in advancing hydrocephalus, and the most striking atrophies, displacements and ventricular herniations are produced at tentorial level (JOHNSON 1953) with little or no clinical change. Herniation of a lateral ventricle through the incisura in a case of astrocytoma of the third ventricle produced severe indentation of the tectal plate (Fig. 2), and may have played some part in the prolonged coma which followed a series of hydrocephalic attacks occurring over a period of five years, and yet between these attacks there were no neurological signs. More commonly the rise of pressure is acute, or acute upon chronic, as in the surface haemorrhage in which severe headache, lowering of conscious level, hemiparesis, rigidities, and pupil changes may advance relent-

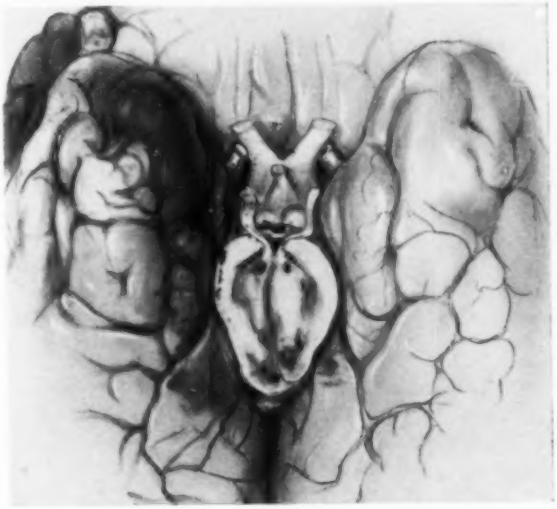
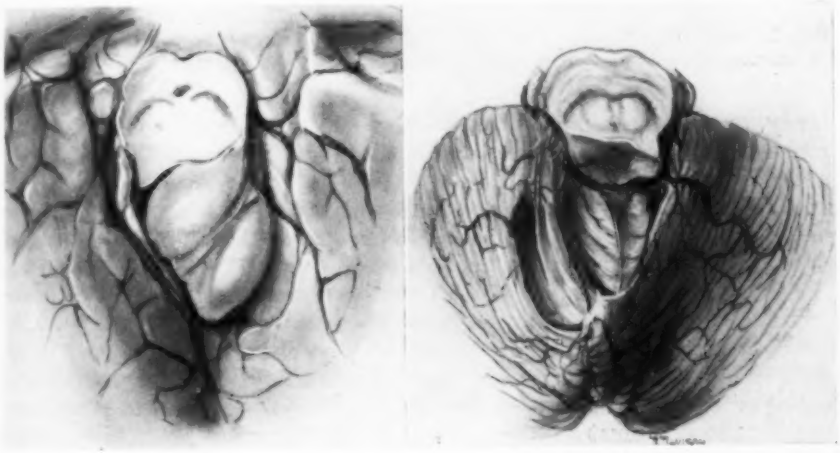


Fig. 1. Ruptured right carotid aneurysm; section of mid brain shows distortion with extensive haemorrhages.



a b

Fig. 2. Hydrocephalus secondary to astrocytoma of 3rd ventricle with herniation of left lateral ventricle through the incisura tentorii. a) Under surface of occipital lobes, showing cystlike hernia lying in cisterna venae gali magna. b) Upper surface of cerebellum deeply hollowed by the hernia which has compressed the dorsal mid brain.

Fig. 3. Right frontal malignant astrocytoma; oedema of whole of right hemisphere involving right uncus, right mammillary body, right peduncle and mid brain.

lessly, or as is more usual with partial remissions, until the condition is irreversible, or as in the brain tumour or abscess where a slight or moderate degree of incisural "packing" becomes rapidly progressive because either the lesion has increased in size, and perhaps in addition has produced obstructive hydrocephalus or, most important of all, oedema is spreading from the abscess or tumour to involve the whole hemisphere including the uncus, and is sweeping down into the brain stem; this by itself may produce signs of mid brain disorder (Fig. 3).

It is in the cases where the rise of pressure is rapid but not catastrophic, that the clinical signs may be correlated with the pathological changes. Acute mid brain compression is a state from which improvement or deterioration must soon occur, and so only the gross changes in neurological function will become apparent in the limited space of time. These changes were extensively reviewed by JEFFERSON in 1938. Worth mention however are two additional neurological disturbances which we have observed — (1) diabetes insipidus, which, although we are uncertain of the pathology, we believe can be caused by downward displacement

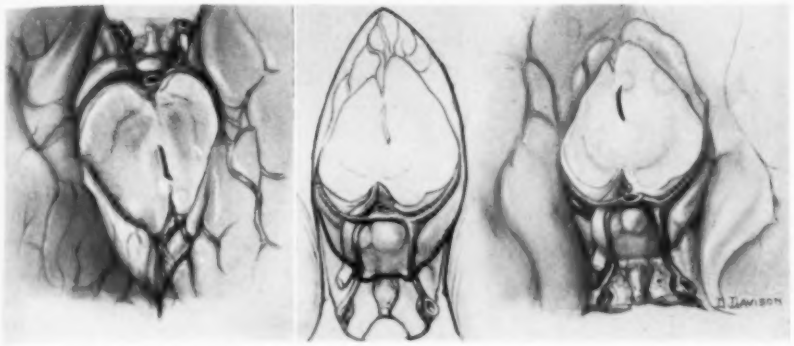


Fig. 4. Right parietal malignant astrocytoma; section of mid brain at tentorial level. *Left:* Posterior herniation compressing the dorsal mid brain. *Middle* and *right:* Extensive downward herniation with grooving of the 3rd nerves (right removed), posterior communicating arteries and base of the pituitary stalk by the petro-clinoid ligaments and dorsum sellae (heavy line in middle view). *Lower right:* Downward displacement of the mammillary bodies and angulation across dorsum sellae — diagram in sagittal plane.

(Fig. 4), and (2) loss of upward movement of the eyes, which we hope to show is an indication of posterior temporo-occipital encroachment on the incisura.

Raised pressure above the tentorium may simply displace the mid brain downwards, and the movement may be extreme as in the case illustrated (Fig. 4), in which the subthalamic region is angulated across the clivus, and the posterior clinoids and the base of the pituitary stalk crushed, a possible cause of diabetes insipidus and pituitary necrosis, if survival is sufficiently prolonged.

Lesser degrees of downward displacement may angulate the 3rd nerves across the petro-clinoid ligaments (BLACKWOOD and his colleagues 1949, LAZORTHES 1955) producing varying degrees of 3rd nerve palsy, and this may occur in the presence of quite a small uncal herniation. In fact the anterior uncal cone has been credited with an importance relative to the pathology of mid brain compression which it hardly merits, probably because indentation of the uncus, especially if swollen, by the upper edge of the tentorium can be so striking post-mortem, if rising venous tension from respiratory embarrassment has produced agonal brain swelling. There is no doubt, of course, that a swollen uncus may indent the peduncle and optic tract (JEFFERSON 1938), but such

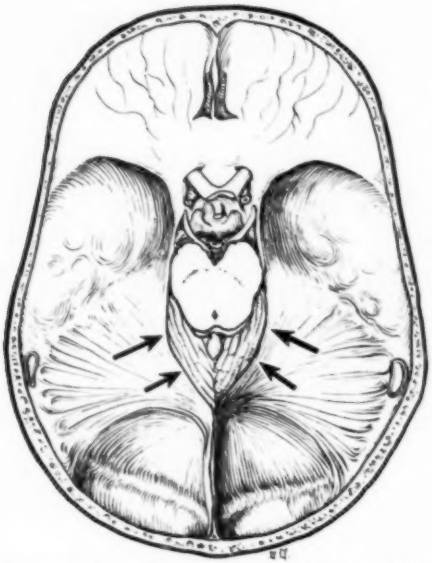
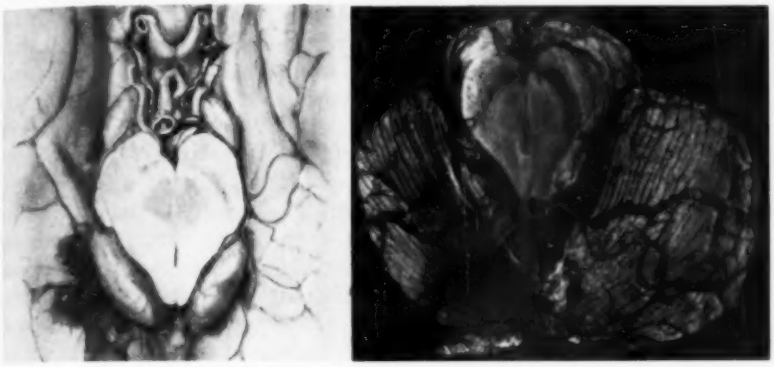


Fig. 5. Diagram of the tentorium cerebelli showing how expanding cerebral hemispheres will tend to slide medially across the flat middle section of the tentorium (arrows), to compress the dorsal mid brain.

indentation may occur above the level of the tentorial incisura. Medial herniation of the anterior uncus over the cavernous sinus into the cisterna chiasmatis, however, produces little neurological effect until rising pressure drives its posterior extremity down into the cisterna prepontis, angulating the 3rd nerves on the petro-clinoid ligaments, and obstructing the subarachnoid pathways (Fig. 6, a and b). It is this displacement which may be demonstrated radiographically by depression of the first part of the posterior cerebral artery, and the sharp upward step as it crosses the tentorial edge. But demonstration of the presence of an uncal cone does not have any immediate clinical significance, for removal of the tumour itself is usually followed by a smooth recovery. In cases with clinical evidence of severe mid brain compression, division of the tentorium and removal of the uncus is not infrequently disappointing; indeed exactly the same pathology may be discovered if the tentorial edge is exposed and divided, following the removal of most large temporal tumours in patients who show no sign of mid brain disorder. It is not surprising, therefore, that reports on the efficacy of tentorial division and reduction of the uncal cone are sometimes conflicting; other factors are playing a part in the mid brain disturbance.

The most striking displacement, and the one which we believe to be the most important is side to side compression and resultant antero-posterior elongation of the mid brain by medial movement of the posterior temporo-occipital lobes. This type of herniation may be overlooked unless the brain is fixed in situ, or is examined immediately and particular attention paid to the shape of the sectioned mid brain for, occurring last, the impression of the tentorial edge will rapidly fade. Unexpectedly, perhaps, it was, in its most striking form, a feature of frontal lesions; the apparent anomaly of frontal lesions producing most



a b

Fig. 6. Chronic bilateral subdural haematoma. a) Section of mid brain at tentorial level under surface of cerebral hemispheres. The posterior part of the uncus and 3rd nerve are grooved by the petro-clinoid ligament. The dorsal mid brain is severely compressed by a posterior herniation of the temporo-occipital lobes. b) Upper surface of cerebellum, grooved by the posterior herniation. The mid brain shows the pear shaped distortion characteristic of posterior herniation.

commonly a posterior cone, finds an explanation in the shape of the dural compartments of the cranial cavity.

When increase of pressure occurs above the tentorium, movement will occur towards the incisura, and unless a space occupying lesion has previously pushed a swollen uncus medially over the tentorial edge, the depth of the temporal fossa and the cavernous sinus in front (JEFFERSON 1938), and the depth of the occipital fossa and the falx behind, will tend to restrict medial movement of the hemispheres to the middle section of the tentorium, where they can slide across the gentle slope to compress from side to side the posterior half of the mid brain (Fig. 5) and simulate clinically a lesion of the tectal plate. Loss of upward movement of the eyes has been observed on many occasions. In four patients (two with frontal cysts, one with a frontal abscess, and one with bilateral subdural haematomas), who were conscious and able to walk about, this feature was so striking that a diagnosis of pineal tumour was made. At autopsy, on two of these patients, the typical pear shaped distortion of the mid brain with posterior herniation was observed (Fig. 6). The other two patients recovered. Although it is only possible to guess the degree of mid brain compression, which results in loss of upward movement of the eyes and pupillary changes, loss of consciousness and finally death (nor must fatal damage in other situations be overlooked because of preoccupation with the mid brain), it is likely

that the gross changes at tentorial level were not dissimilar in the four cases. This type of mid brain deformity is a highly dangerous state in which the slightest advance will produce irreversible mid brain ischaemia, and the eye changes provide clinical evidence of its presence. It is a change which can occur in the absence of actual herniation, *i. e.* the mid brain may be compressed from side to side without downward displacement, although in most cases the two are inseparable. Clinically, loss of upward movement may be demonstrated in an unconscious patient, as long as the cornea remains sensitive, and is a valuable sign in the absence of the Hutchinsonian pupil, indicating for the most part a frontal lesion or generalised brain swelling. Side to side compression of the mid brain by the movement of the expanding temporo-occipital lobes across the middle section of the tentorium, not only induces ischaemia of the tectal plate and tegmentum but elongates the mid brain from front to back, and so the problem was posed of whether deformity of the mid brain, divorced from stretch of downward displaced vessels, from venous engorgement, and from sudden disruptive movement, could result in mid brain haemorrhage.

It is a great pleasure to thank Miss DOROTHY DAVISON and her pupil Miss WHITTAKER for the beautiful and accurate drawings, and to thank Dr. ROBERT OLLERENSHAW of the Department of Medical Illustration, Manchester Royal Infirmary, for the photograph (Fig. 6 b).

SUMMARY

The pattern and degree of mid brain deformity and the associated clinical manifestations, are determined by the site of a space occupying lesion, whether or not it has induced oedema spreading into the uncus or mid brain, and its rate of development. Loss of upward ocular movement occurs in certain stages of posterior herniation of the temporo-occipital lobes which produce a characteristic pear shaped deformity of the mid brain. This was most commonly found in association with frontal lesions and generalised oedema, but the ocular signs were sufficiently striking in conscious and ambulant patients to suggest the diagnosis of a tumour in the pineal region.

ZUSAMMENFASSUNG

Das typische Bild und das Ausmass der Deformierung des Mittelhirnes und die damit zusammenhängenden klinischen Manifestationen sind durch die Lage eines raumverdrängenden Gebildes und durch die Tatsache, ob dieses die Ausbreitung eines Ödemes in den Uncus oder das Mittelhirn veranlasst hat oder nicht, sowie durch die Entwicklungsgeschwindigkeit des Gebildes, bestimmt. Der Verlust der Augenbewegung nach oben entsteht in gewissen Stadien der Verschiebung der Temporo-occipitallappen nach hinten, wodurch eine charakteristische birnenförmige Deformierung des Mittelhirnes entsteht. Dieses fand man am häufigsten zusammen mit Erkrankungen der Frontalregion und generalisiertem Ödem, aber die Augensymptome waren bei wachen und ambulanten Patienten deutlich genug, um die Diagnose eines Tumors in der Gegend des Corpus pineale zu ermöglichen.

RÉSUMÉ

La forme et le degré de la déformation du mésencéphale et les manifestations cliniques associées sont déterminés par le siège de la tumeur, par le fait qu'elle a ou non causé un oedème s'étendant dans l'uncus ou dans le mésencéphale et par la rapidité de son développement. Une paralysie de l'élévation du regard se produit à certains stades de la herniation en arrière des lobes temporo-occipitaux, qui cause une déformation en poire caractéristique du mésencéphale. C'est en association avec des lésions frontales et avec un oedème généralisé que ceci a été le plus souvent constaté, mais les signes oculaires ont été assez nets chez des malades conscients et ambulatoires pour faire évoquer le diagnostic de tumeur de la région pinéale.

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FROM THE MANCHESTER ROYAL INFIRMARY AND THE UNIVERSITY OF MANCHESTER, MANCHESTER, ENGLAND

BRAIN STEM HAEMORRHAGES IN EXPANDING SUPRATENTORIAL CONDITIONS

by

R. T. Johnson and *P. O. Yates*

Space occupying conditions of the cerebral hemispheres give rise to two groups of clinical signs and symptoms: those caused by pathological changes at the site of the lesion and those which cannot be so related. Many of the latter false localising signs can be ascribed to damage of the brain stem and are a non-specific effect of expanding lesions filling the supratentorial space. They are found whatever the nature of the primary disease, whether haemorrhage, tumour or oedema.

When the evidence of brain stem damage is slowly progressive, some compression and displacement of the midbrain and pons is usually present; the ischaemic effects produced by partial closure of the capillary bed may be reversible. However, when the signs are of an acute and catastrophic nature, or when there is sudden exacerbation of a previously mild state, we find at necropsy not only distorsion of the brain stem but also haemorrhages within its substance. We believe that these haemorrhages are produced by arterial rupture, and it is the resultant disturbance of blood supply and not the haematoma which causes the fatal damage.

The view has often been put forward that the bleeding is from veins; the result of venous engorgement. It is important to arrive at some certainty on this point for relief of venous obstruction may be surgically possible, whereas arterial rupture has graver and more permanent implications for the tissues supplied. One of the earliest writers on this subject was ATTWATER (1911) who reported 67 cases of secondary pontine haemorrhage, for the most part occurring in cases of massive cerebral haemorrhage. He thought that a combination of raised intracranial pressure and degeneration (presumably atheromatous) of the pontine artery might be responsible. GREENACRE (1917) was concerned to explain

the occurrence in cerebral thrombosis and she suggested that when, for example, the middle cerebral artery was occluded, the additional blood flow diverted down the posterior communicating artery from the carotid might prove too great a strain for the branches of the basilar trunk. In 1923, however, BAGLEY, reporting cases of multiple haemorrhages into basal ganglia and brain stem, suggested that the lesions were due to engorgement of the vein of Galen. STOPFORD (1928) pointed out that compression of this vein could occur between the tentorium and the splenium of the corpus callosum.

Fig. 1. Section from the midbrain of a case in which rupture of an aneurysm caused sudden distension of the ventricular system and periaqueductal venous haemorrhages.

On the other hand, WILSON and WINKELMAN in 1926 thought that a general rise of intra-cranial pressure flattened the pons and basilar artery against the base of the skull, disturbing the circulation to the small pontine vessels. MOORE and STERN (1938), recognising that a disparity in pressure above and below the tentorium was the most significant feature in causing brain stem haemorrhages, suggested that this resulted in a damming back of the blood flow up the basilar artery with distension of the pontine arteries. The rise in systemic blood pressure which they had noted in many of their patients would enhance this effect and rupture the already distended pontine arteries.

More recently SCHEINKER (1945 and 1952) has strongly upheld the view that the brain stem lesions are secondary to venous engorgement, following compression of the larger veins leaving the upper brain stem. He stated that the small haemorrhages were often to be found around venules, though he said that it was more difficult to be certain of the origin of the larger haemorrhages. CANNON (1951) pointed out that the blood spreads out between the fibre tracts and runs along the course of the paramedian penetrating arteries. However, he concluded that they were caused by venous stasis at the tentorial opening. This view was also supported by POPPEN et coll. (1952), though they do comment on the finding of patchy necrosis of the walls of arteries in some of their cases and accept the fact that these arterial lesions may play some part.

We have not found distension and engorgement of the venous system around the brain stem in cases showing mid brain or pontine haemorrhages. Only rarely have we found what was obviously venous bleeding, and in these cases the haemorrhages were clustered beneath the ependyma of the aqueduct and fourth ventricle (Fig. 1). Such lesions seem

Fig. 2. Diagrammatic representation of the way in which downward displacement of the dorsal part of the brain stem produces distortion of the long penetrating arteries and rupture of their terminal branches.

Fig. 3. Photograph of specimens corresponding to fig. 2. The abnormal brain stem is from a case of massive cerebral haemorrhage. The secondary haemorrhages run down beside the distorted pontine arteries.

to occur where there is a sudden expansion of the ventricular system, as when an aneurysm ruptures into a ventricle causing a downward wave of C. S. F., interestingly similar to the mechanism suggested by Duret to account for concussion.

The haemorrhages which we find in the midbrain and upper pons occur particularly at the point of branching of smaller arteries. The blood may track back to ensheath the long penetrating arteries which run directly through the brain stem from front to back. An explanation of the mechanism of production of these haemorrhages is to be found in the consideration of two displacements at the tentorial opening. The first is a downward displacement of the brain stem. Some of the branches of the basilar artery, which supply the midbrain and pons, run in at right angles to the axis of the brain stem, passing through to supply the tegmental and periaqueduct regions.

DOTT and BLACKWOOD (1951) have suggested that the upper end of the basilar artery is well anchored to the tentorial edge by the posterior cerebral branches and via the posterior communicating artery to the internal carotid artery fixed in the cavernous sinus. A downward displacement of the brain stem would cause the penetrating arteries to lie obliquely and be elongated. The tension transmitted during such a manoeuvre to the terminal arterial branches, results either in vasospasm or in active rupture of the vessel walls. We do not think fixity of the basilar artery is essential to this explanation. The posterior part of the brain stem is moved downwards more than the anterior part, and it is the distortion of the vessels in their path within the brain stem resulting from this irregular shift which tears the smaller arterial branches (Figs. 2 and 3).

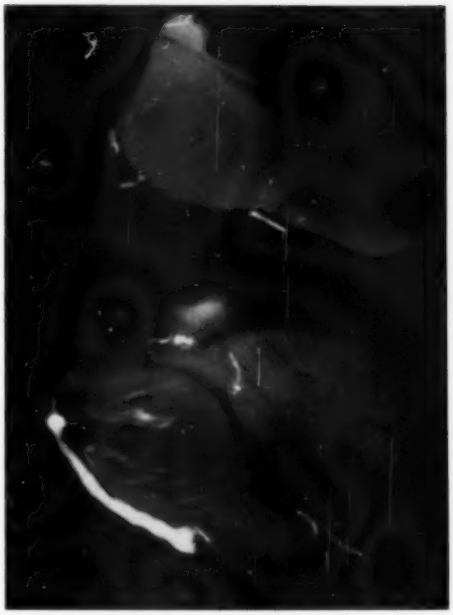

Fig. 4. Radiographs of two sagittal median slices of brain stem, injected at necropsy with a silver iodide mixture. Upper section is from normal brain and shows normal arterial pattern. Lower section is from a case of cerebral abscess with oedema in which secondary brain stem haemorrhage had occurred in life. The radioopaque material has run into the haematomata.

One of us (YATES) has made angiographic roentgen studies of injected brains in which there were secondary brain stem haemorrhages. The injection mass, consisting of 10 % silver iodide in gelatin, was introduced into the carotid and vertebral arteries in the neck under a pressure of 120 mm Hg at necropsy. Prior to injection, the cerebral vessels were perfused with warmed saline in order to clear them of blood, though this did not, of course, affect the haematomata in the brain stem. The material leaked from the terminal branches of the pontine arteries to join the ante-mortem haemorrhage and flowed back alongside the arteries, mixing with the blood which had presumably followed such a pathway before death. The injection material was such that it would not pass from the arterioles to the capillary bed and venules, nor did any escape of radio opaque material occur when brains which had not undergone brain stem

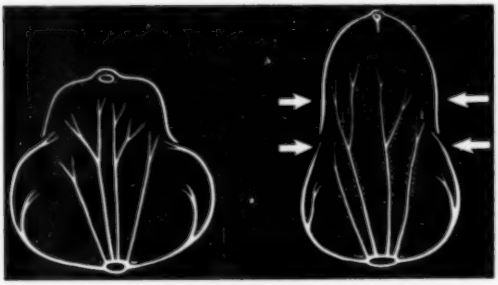

Fig. 5. Diagram illustrating the mechanism by which lateral pressure may, if appropriately applied, cause elongation of the long penetrating arteries and haemorrhages which run back alongside the vessel.

haemorrhage before death were injected by this technique. The fact that it leaked readily into the small haematomata strongly supports the view that these had resulted from ante-mortem arterial ruptures (Fig. 4).

The arterial lesions are not confined to the brain stem for we have found in such cases recent infarction of the cortex of part of the anterior lobe of the cerebellum, which is commonly supplied by long vessels arising near the origin of the superior cerebellar arteries. These long vessels are also subjected to considerable tension by the same downward shift.

Not all cases with haemorrhages in pons and midbrain show an obvious downward shift. The second displacement which must be considered is the lateral movement of the temporo-occipital lobes across the tentorial opening, which is found in many cases of supratentorial expansion. By this mechanism the midbrain is flattened from side to side, distorting the normal rounded outline to an elongated and flattened oval. The antero-posterior dimension of the midbrain may increase by more than 1 cm. When this occurs suddenly, in cases with rapidly expanding supratentorial lesions, the long penetrating arteries running from the interpeduncular space to the tegmental region are stretched and embarrassed (Fig. 5). This may enhance the effect of the downward shift. Such a mechanism was readily demonstrated at necropsy. The vertebral arteries of normal brains were injected with various opaque and radio opaque substances of such a nature that they did not penetrate to the capillary bed. Provided that a pressure of not more than 150 mm Hg was used, no artificial disruption of arteries was produced. At other times, the upper pons and midbrain were compressed laterally, sufficient to produce the degree of distortion which was known to occur in disease. If in this situation the vertebral arteries were injected at 120 mm Hg the injection material escaped from the torn terminal branches of the long penetrating arteries (Figs. 6 and 7). These simulated haemorrhages, which so strikingly mimic those occurring before death, suggest that lateral compression alone may be an adequate explanation of the haemorrhage in some cases.

Fig. 6. Radiograph of a transverse slice of pons from a normal brain. Whilst the arterial injection of silver iodide mixture was being carried out at necropsy, lateral pressure was applied to upper pons and midbrain. The resulting "haemorrhages" closely simulate those occurring naturally.

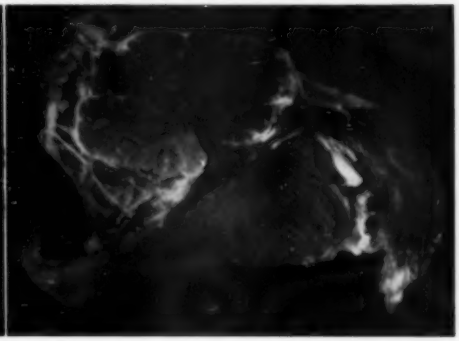

Fig. 7. Photograph of a cleared longitudinal slice of a normal brain stem. Here, a similar experiment to that illustrated in Fig. 6 was carried out. In this case, lateral pressure was applied only to the midbrain, and the resultant "haemorrhages" are confined to this region.

SUMMARY

Brain stem haemorrhages secondary to raised supratentorial pressure are the result of arterial rupture. Two distortions of the mid brain and upper pons are responsible for the tearing of branches of their long paramedian arteries. Firstly, antero-posterior elongation of the mid brain is caused by lateral compression between displaced and herniated hippocampal gyri; secondly, downward displacement of the posterior part of the pons increases the antero-posterior dimension. Angiographic study of brains injected at necropsy confirmed the arterial nature of the haemorrhagic lesions.

ZUSAMMENFASSUNG

Im Anschluss an eine supratentorielle Drucksteigerung entstehende Hirnstammblutungen sind das Ergebnis einer arteriellen Ruptur. Zwei Verschiebungen des Mittelhirnes und des oberen Ponsabschnittes sind für das Zerreissen von Ästen ihrer langen paramedianen Arterien verantwortlich: erstens, die anterio-posteriore Verlängerung des Mittelhirns, welche durch die laterale Kompression zwischen den verlagerten Windungen des Hippocampus verursacht wird, und zweitens die anterio-posterioren Verlängerung der Pons welche durch die Verlagerung ihres posterioren Abschnittes nach unten verursacht wird. An Sektionsmaterial vorgenommene angiographische Hirnstudien bestätigten die arterielle Natur der haemorrhagischen Befunde.

RÉSUMÉ

Les hémorragies du tronc cérébral secondaires à une augmentation de la pression sus-tentorielle sont le résultat d'une rupture artérielle. Deux distorsions du mésencéphale et du haut de la protubérance sont responsables de la déchirure des branches de leurs longues artères paramédianes. Premièrement, l'élongation antéro-postérieure du mésen-

céphale est causée par sa compression latérale entre les circonvolutions de l'hippocampe déplacées et herniées; deuxièmement, le déplacement vers le bas de la partie postérieure de la protubérance augmente sa dimension antéro-postérieure. L'étude angiographique de cerveaux injectés à l'autopsie a confirmé la nature artérielle des lésions hémorragiques.

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ANOTHER METHOD OF VERTEBRAL ANGIOGRAPHY

by

E. Lindgren

There are practically only two methods at present for carrying out vertebral angiography, *i. e.* percutaneous puncture of the vertebral artery and RADNER's catheter method. We have used the percutaneous method almost exclusively in our Department, and with the present technique and experience we have been successful at the first attempt in about 70 % of the cases. Real difficulties, or obstacles, have been encountered in about 10 % of the cases.

Some years ago we tried the catheter method according to RADNER, but we found this method circumstantial, and if it is to give good results it appears that considerable training is required. We are also of the opinion that such procedures should if possible be avoided where sterility and screening facilities are required at the same time. The method in experienced hands can undoubtedly produce good results, but it is nevertheless evident that even a trained examiner is not always successful in placing the tip of the catheter in the right position. What is more serious is, however, that for users of the catheter method complications seem to arise in remarkably great numbers. Thus, HAUGE in 1954 published an extensive monography on vertebral angiographies, in which he reported a very large number of cerebral complications. Most of them were of small significance but there were also serious complications, and even deaths.

We consider, however, that the examination with the percutaneous method is practically without risks. Anyway, the complications in our experience do not amount to as much as 0.5 %. That complications may follow when the catheter method has been employed is, in my opinion, not so much due to the method in itself but are consequences of the fact

Fig. 1. The position of the catheter in the subclavian artery. The vertebral artery is filled with contrast medium.

that the catheter, which is a foreign body in the vessel, partly obliterates the lumen. It is also a common experience that a catheter introduced into a comparatively narrow vessel very often causes spastic contractions. The concentration of the contrast medium will thus be greater than after injection of the contrast medium into the vessel through a needle.

Since the percutaneous method, however, cannot be employed in all cases, and since I feel that the catheter method of RADNER should be avoided, I have used another catheter method, based on the one I have been practising for some years for renal angiography. The femoral artery is punctured percutaneously with a comparatively thick cannula through which a catheter of polyethylene is inserted into the aorta up to the aortic arch. The left femoral artery is usually punctured because on this side the iliac artery often has a straighter course than on the right side, and because it appears as if the catheter slips into the subclavian artery easier from the left than from the right side. When an approximately correct position for the catheter has been obtained, a test injection is made in order to localize more precisely the tip of the catheter and in order to determine the course taken by the contrast medium. The catheter position may if necessary again be adjusted. Should it be difficult to introduce the catheter into the subclavian artery, the tip may be lying in that part of the aorta from which the artery probably originates. If in such cases the quantity of contrast medium injected during the examination proper

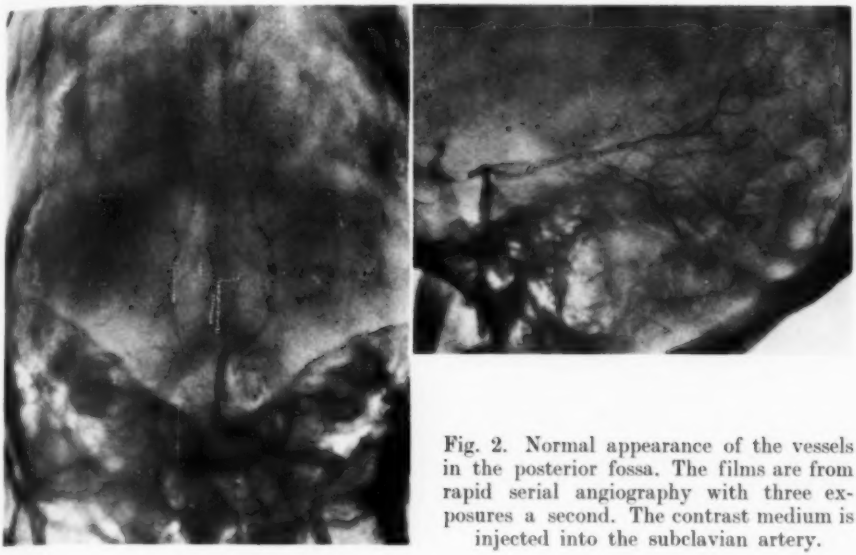

Fig. 2. Normal appearance of the vessels in the posterior fossa. The films are from rapid serial angiography with three exposures a second. The contrast medium is injected into the subclavian artery.

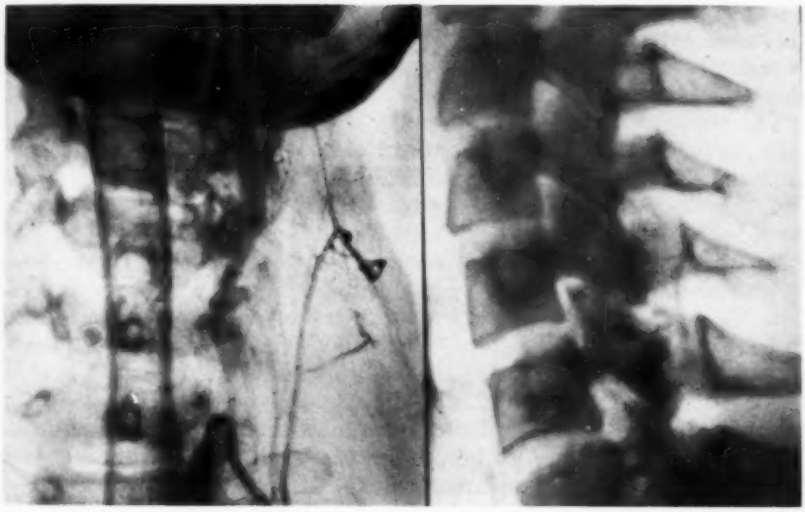

Fig. 3. Arteriovenous malformation in the intervertebral foramen between C 4 and C 5, extending into the intervertebral canal. Injection into the subclavian artery.

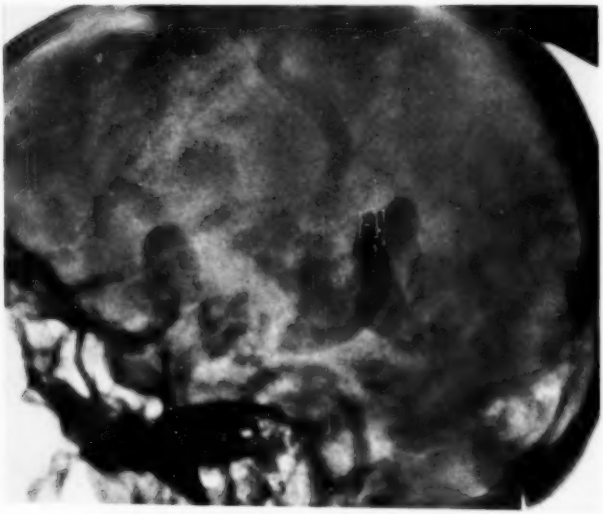

Fig. 4. Large arteriovenous malformation, contrast filled by injection into the aorta in the vicinity of the point where the subclavian artery originates.

is larger than that used when the point of the catheter lies in the subclavian artery itself, sufficient amounts of contrast medium will pass through the subclavian artery into the vertebral artery and its intracranial branches.

The position of the catheter point is demonstrated in Fig. 1. With the catheter in such a position, 15 ml of contrast medium is generally employed. This year we have used Triurol 35 % or 50 %, a Swedish Urokon preparation. When the catheter, as in these cases, is inserted into a fairly wide vessel, it does not affect the blood stream through the vessel as much as it would have done if it had been placed in the vertebral artery; nor does it, as far as I have noticed, cause any spastic contractions. The examination is always performed under general anaesthesia. We have no great experience of the method, since in most instances we make use of the percutaneous method, which is more simple. Yet, in all the 10 cases for which this technique has been used, satisfactory views of the vessels of the posterior fossa have been obtained. As a matter of fact, the method can also be used in cases where it is desirable to be able to study the vertebral artery along its entire course in the neck. If for some reason the percutaneous method should fail, it is my belief that vertebral angiography can be performed in this manner with less risks than those entailed when the catheter is placed in the vertebral artery.

SUMMARY

A technique for vertebral angiography with injection of the contrast medium into the beginning of the left subclavian artery, or in the aorta is described.

ZUSAMMENFASSUNG

Eine Technik der vertebralen Angiographie mit Injektion des Kontrastmittels in den ersten Abschnitt der linken A. subclavia, oder in die Aorta wird beschrieben.

RÉSUMÉ

Description d'une méthode d'angiographie vertébrale par injection du produit de contraste dans l'artère sous-clavière gauche à son origine, ou dans l'aorte.

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BIPLANE STEREOSCOPIC CEREBRAL ANGIOGRAPHY

by

Herbert M. Stauffer, Frederick Murtagh, John F. Mokrohisky, and *Robert E. Paul, Jr.*

This paper is based on an analysis of more than 400 cerebral angiographies performed with the CHAMBERLAIN biplane stereoscopic apparatus and using Urokon 30 %.

Our three-dimensional concept of the world is due largely to the fact that corresponding areas in the two retinas receive slightly dissimilar images of any given object. Stereoscopic radiography has been condemned in some quarters on the ground that it is non-objective. Actually, human visual phenomena, including stereoscopy, to be effective always involve subjective interpretation. Obviously, it is a greater feat of the subjective imagination to reconstruct in the mind's eye a three-dimensional image of the skull and cerebral vessels from a single radiograph than from a pair of exposures studied stereoscopically.

It is quite true that some individuals unfortunately have little or no stereoscopic vision and this has been urged as a drawback of roentgen stereoscopy. The work of BATSON has been quoted in this regard. But it must be emphasized that BATSON was testing radiologists in training and he showed that almost all the doctors tested having poor stereoscopic vision could improve it to useful levels by proper exercises.

Stereoscopic radiography of the skull in all standard projections is so much a part of the routine practice in our institution, due to the influence of EDWARD CHAMBERLAIN, that radiologists and neurosurgeons agree that studies of the skull and its contents are incomplete without it. Thus we feel that useful stereoscopic vision might well be considered one of the qualifications for a career in radiology just as it is for certain other occupations, such as the piloting of aircraft. For those with stereoscopic vision not to apply it in the radiographic study of the skull and its contents is to deprive themselves and their patients of potentially useful information.

Admittedly, the film expense is double but many workers would not hesitate to use multiple tomographic films in diagnostic problems that might be solved by a pair of stereoscopic exposures.

The availability in the roentgen department of stereoscopes ('Stanford'; and F—R) embodying simplicity, close viewing distance and absence of mechanical or optical

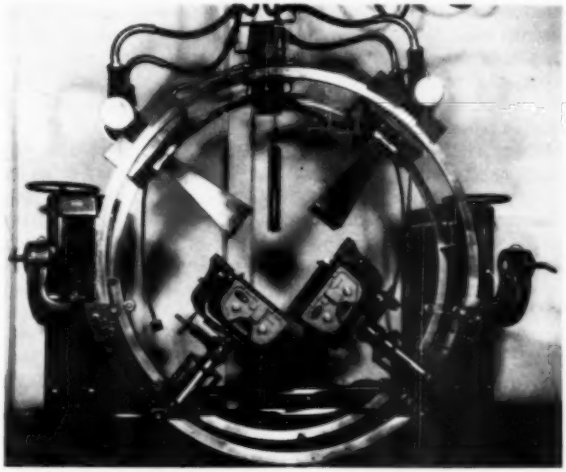

Fig. 1. The Chamberlain biplane stereoscopic angiographic device.

adjustments has been very important in the continued routine application of stereoscopy in our clinical practice, especially in neuroradiology.

Apparatus. The angiographic apparatus designed by CHAMBERLAIN has been used for all cerebral angiograms performed in our institution during the past five years. Two Fairchild roll film magazines are mounted at right angles to each other in a large circular frame with 2 radiographic tubes, one of these being opposite to each of the roll film magazines. Each of the latter accommodates 75 feet of 9-inch wide roll film, and exposures approximately 9 inches square are made at the rate of one every 0.7 second on each magazine, the film therein being advanced between intensifying screens. Crankshaft mechanisms driven by a synchronous motor provide a 2-inch shift of each of the roentgen tubes between exposures, so that each image on each roll of film is stereoscopic with the image before it and following it on the roll. The electric connection of the two roentgen tubes is such that they fire simultaneously. The stereoscopic tube shift is timed to occur while the film is advancing between the intensifying screens. The whole assembly is pivoted so that it can be used with the roentgen ray beams at any angle. Long cones accurately limit the roentgen beams and with high voltage criss-cross Schönander stationary grids mounted in front of each magazine secondary scattered radiation is effectively controlled (Fig. 1).

An important practical feature in working with the apparatus is the ease and rapidity with which angiographic studies, often bilateral at one sitting, can be performed by the experienced operator. The projections employed are standard and are easily duplicated.

Technique of injection. All injections have been made by the percutaneous method using a standard straight 18 gauge needle $2^1/_2$ inches in length. The percentage of successful intra-arterial injections varies directly with the experience of the operator. Success in upwards of 95 % of attempts is obtained by the highly experienced operators and it is felt by them that if the carotid artery cannot be successfully injected by this method

by an experienced person, abnormality of the vessel, such as thrombosis or anomaly, is probably present; such vessel abnormalities are confirmed by direct inspection of the vessel and open arteriography.

Conscious patients without increased intracranial pressure receive pre-operative sedation in the form of 100 mg of nembutal, 1½ hours prior to the procedure, and demerol 100 mg, and atropine 0.4 mg one hour before the procedure.

The patient is placed on the specially designed chair-table in a modified semi-Fowler's position with the head resting on one of the film magazines and the neck extended so that the carotid artery is brought forward and made taut to facilitate entry of the needle. This position of extension is maintained until the needle is properly placed and threaded inside the artery when the position of the head may be altered to obtain satisfactory projections before the contrast material is injected.

Wherever possible local anesthesia is used. This reduces the operative risk, and the patient's subjective response to the injection helps to indicate whether a successful intra-arterial injection or extravasation of the contrast material has occurred. Each step of the procedure is carefully explained to the patient prior to the injection and a remarkably high degree of tolerance of the procedure is obtained. If the patient is uncooperative a small amount of pentothal is given intravenously just prior to the contrast injection, or if necessary during the entire procedure.

The neck is painted with an antiseptic solution and properly draped. A skin wheal is made with 1 % procaine low in the neck at the medial border of the sterno-cleido-mastoid muscle. A loose-barrelled 10 ml syringe is used, half filled with saline solution. A one-way stopcock is interposed between the syringe and the 2½″ 18 gauge needle. The skin is punctured, and the needle is replaced with a new needle for each arterial puncture; the needle is inserted through the skin, bevel up, and directed along the long axis of the carotid artery which is held beneath the fingers of the opposite hand. The anterior surface of the artery is picked up by the sharp point and the needle is then thrust its full length inside the artery. A strong spurt of bright red blood into the syringe denotes successful entry.

Subsequently the head is properly positioned for the roentgen exposures and the syringe of saline is replaced with a 10 ml syringe containing contrast material.

The machine is started and injection of the contrast medium is begun immediately after the first exposure. The contrast is injected rapidly and at the completion of the injection bright red blood should flow freely back into the syringe. If the injection has been successful, the patient will describe a burning sensation over the entire hemicranium on the side of the injection. This sensation may not be experienced by the patient with an arteriovenous fistula or a vascular malformation. If extravasation of contrast material is suggested (absence of this sensation and severe neck pain), the needle is repositioned and a second injection is made.

The contrast material. Urokon sodium (sodium 3 acetylamino-2,4,6 triiodo benzoate) 30 % has been used exclusively in this series.

Eight (8) to ten (10) ml of contrast solution has been used routinely. This amount gives excellent contrast and adequate filling of all phases is assured. Satisfactory studies have been obtained with 5 ml of contrast, and in one instance 2 ml was sufficient to adequately outline the arterial phase. Studies have been obtained with the contrast diluted to 25 % and to 15 %, the latter, however, with poor opacification.

It is our feeling that Urokon is superior to the contrast material we previously used, namely Diodrast. The subjective responses of the conscious patient during the injection of Urokon indicate that it is far less painful than the injection of Diodrast. No cases of drug sensitivity have been encountered. Flushing of the skin or pupillary dilatation have not been observed.

In this series there have been one death and five minor complications which we feel can be attributed to the passage of contrast substance through the cerebral vascular tree.

A 40-year-old woman with clinical signs of primary cerebro-vascular disease expired 48 hours after cerebral angiography. Immediately after the procedure she became stuporous and there was marked increase in the neurologic deficit. It is our feeling that the procedure in this instance was ill-advised.

There were two patients with the clinical diagnosis of cerebro-vascular disease who, within 4 minutes after the injection of the contrast had been completed, became unconscious and then developed transient decerebrate rigidity. Hemiplegia was apparent following the decerebration but cleared rapidly. A third patient, with bilateral cerebral thrombosis, was unconscious and hemiplegic for several days following arteriography. All three of these patients exhibited marked prolongation of the arterial phase in their angiograms. One additional patient complained of severe pain in the eye and of visual blurring for several days following the injection of Urokon.

It has been of great interest to us to note the recent communication by ODÉN indicating that Triurol, a Swedish preparation apparently identical chemically with Urokon, has been found less irritating for cerebral angiography than Umbradil in comparative studies at the Seraphimer Hospital.

Although ODÉN has emphasized the absence of irritative effect with Triurol in cases examined soon after head trauma, one of our complications occurred in such an instance. Angiography was performed on an 18-year-old boy with a recent contusion of the left parietal cortex. Following the study, weakness in the right upper extremity progressed to paralysis and total aphasia was present. These persisted for approximately 15 to 20 minutes before return to the pre-operative state.

Stereoscopic cerebral angiography. Stereoscopy is in the authors' opinion eminently successful in cerebral angiography. Almost without exception two successive films show enough of the arterial phase to yield a useful stereoscopic image; the much slower venous phase never posed any problem in this regard.

We rely on stereoscopy in cerebral angiography primarily for identifying vessels, normal and abnormal, in both the a.p. and lateral projections. No attempt need be made to evaluate possible lateral displacement of the midline vessels in the lateral projections (Fig. 2).

We have found stereoscopic study of a.p. projections much more reliable for detecting vessel displacement from the sagittal plane than measurements made from the individual films. The relatively unyielding falx, well localized by opacification of the arteries and veins ranged along it, provides the most satisfactory plane of reference for evaluating lateral shift of the anterior cerebral artery and the internal cerebral vein. In fact, from our experience, we have grave doubts as to the validity of identification in the a.p. of midline vessels and of the presence or absence of minimal degrees of shift without the benefit of stereoscopic study.

Similarly, displacement of the peripheral vessels from the inner table (as in subdural hematoma) may be appreciated much more readily and fully in stereoscopic than in single a.p. film studies.

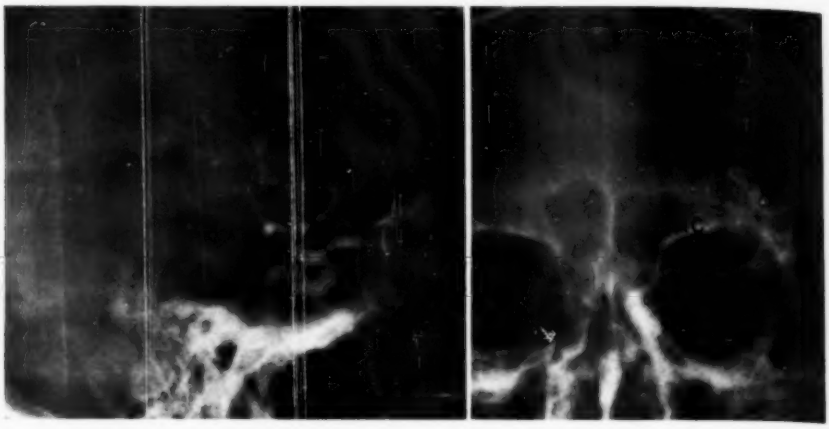

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Fig. 2. Arterial phase. a) Lateral view. Arrow indicates vessel which can be identified by stereoscopy as the anterior cerebral artery displaced posteriorly by an anterior fossa tumor. b) Corresponding, simultaneous a.p. view. Arrow indicates anterior cerebral artery.

Stereoscopic study in a.p. and lateral projections is not a substitute for special projections (oblique, half-axial or submento-vertex) when they are indicated. These require the additional hazard of additional injections of contrast material; stereoscopy in the oblique projections enhances their value.

Simultaneous biplane exposures. The chief aim in the development of this apparatus was to reduce the risk to the patient by minimizing the number of injections and the quantity of contrast required for each. The biplane feature is paramount in this important accomplishment.

The biplane feature often is crucial for positive identification of a particular vessel in the a.p. and lateral projections when transient contrast filling is so rapid that the vessel may appear in only one pair of simultaneous exposures in the series.

Misinterpretation may be avoided by study of simultaneous biplane exposures when there are variations in the pattern of arterial, and particularly of venous, filling on successive injections. This is especially true if there is displacement or other abnormality of the vessels. Thus, in the a.p. and lateral projections recognition of pathologic vessels can reliably be made when the circulation through a lesion occurs rapidly, as in some tumors and in vascular malformations.

The phenomenon of 'layering' of the heavy contrast material especially in the distal portion of the internal carotid artery can be recognized.

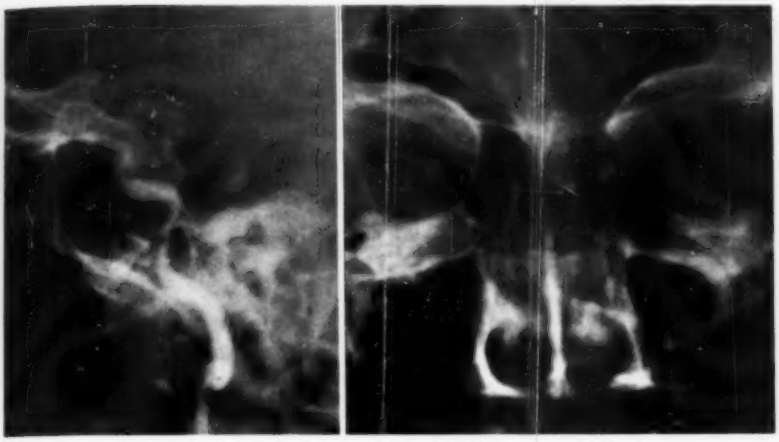

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Fig. 3. a) Lateral projection. Arrow indicates area of thinned column of contrast medium in the distal portion of the internal carotid artery. b) Corresponding, simultaneous lateral view demonstrates wide, less dense contrast column in same portion of carotid artery. This establishes the phenomenon of layering.

Without simultaneous biplane exposures the appearance of a thinned column of contrast in the lateral projection might be misinterpreted as due to a spasm; a wide but less dense vessel in the corresponding a.p. exposure denotes layering on the dependent surface of the vessel lumen (Fig. 3). Such layering is also sometimes seen in aneurysms.

It has been our practice for the first exposure in the series to be made before contrast has entered the cranium. In fact, the making of this exposure is the signal for the operator to begin the injection. A total of 12 exposures in each plane has been our routine practice. This means that approximately 7 seconds elapse between the beginning of the injection and the making of the final exposure. This timing has almost always demonstrated the venous phase except in rare instances when there was unusual prolongation of the arterial phase.

We have repeatedly attempted to reduce the number of exposures needed by selecting certain periods to be omitted but have invariably decided that it was impossible to predict the time at which it would be safe to omit exposures.

This complete sequence has been of value in recognizing tumor circulation. With such studies a variety of types of abnormal circulation may be recognized within the same tumor; with only a single film in each phase of the cerebral circulation the lesion might have been classified

as having one or the other of these 'specific' types of vascularization alone.

A major factor limiting the spread of use of this method undoubtedly is economic. The disadvantages of the considerable initial cost of the apparatus, available commercially, and the additional film expense are offset to a great extent, at least in our opinion, by the decreased amount of contrast material required, the convenience provided and by the possibility of obtaining additional important clinical information.

The roll-film magazines we have used are responsible for some reduction in definition, of varying degree, due to poor screen contact. They also give rise to occasional mechanical pressure artefacts. The film size should be larger since we would prefer to include on the film the needle and the skull vertex which is impossible with the present film dimensions. The present magazines can be replaced by improved versions when they become available.

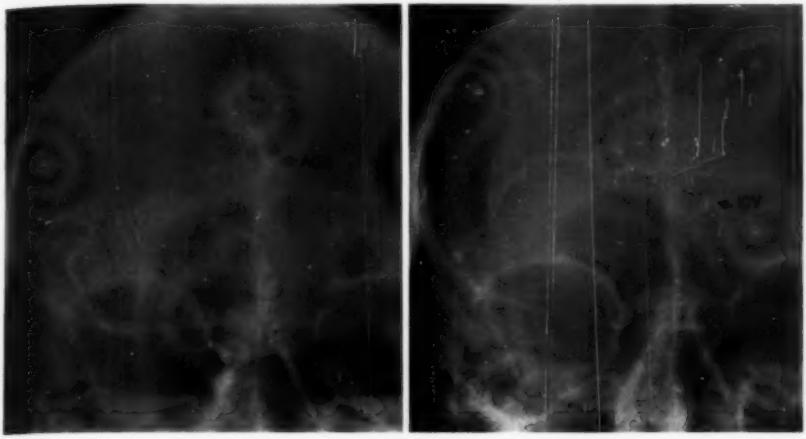
Until now roentgen evidence of successful contrast-filling of the intracranial circulation has necessitated exposing and processing the entire sequence of films. Provisions for fluoroscopic visualization at the time of injection are under consideration.

It has not been feasible with our apparatus to position the patient for half-axial or submento-vertex projections, still keeping the needle in the arterial lumen. This important limitation might be overcome by the introduction of a catheter through the needle into the lumen of the artery.

Observations from clinical material. We have found biplane stereoscopic studies, with serial exposures through the arterial and venous phases of the angiogram, of aid in making a definite decision as to whether or not tumor circulation was recognizable. We were able to identify abnormal circulation in approximately 68 % of proved cases of meningioma, a somewhat higher percentage than reported by others. On the other hand, we have been surprised to find that we have identified pathologic circulation in only about 35 % of our gliomas regarded as highly malignant histologically. A possible cause of this discrepancy may be the method of histologic grading since very few low-grade astrocytomas were reported.

Stereoscopy has been of aid in recognizing the external carotid arterial supply to meningiomas.

Displacement of vessels away from the inner table of the skull has been pointed out as a distinguishing feature of meningiomas. It seems equally important to emphasize that in many cases global meningiomas sink into the brain. Stereoscopically it is easy to recognize cerebral vessels almost completely surrounding such a tumor and it certainly



a b

Fig. 4. Glioma in mid-portion of hemisphere. Note minimal lateral displacement of anterior cerebral artery in (a) and pronounced lateral shift of internal cerebral vein in (b).

would be extremely difficult by any method to prove the extra-cortical origin of the lesion.

As mentioned previously, the complete series of exposures through both the arterial and venous phases made routinely has demonstrated that one tumor may exhibit a variety of types of pathologic circulation.

Both the stereoscopic and the simultaneous biplane features have proved their value to us in identifying the collateral circulation which is developed in cases of thrombosis, particularly of the internal carotid artery.

To us the single most valuable item in the entire phlebogram is the demonstration of lateral displacement of the internal cerebral vein. Stereoscopy is invaluable for demonstration of minimal displacement of this vein, aided by observing its relationship to the visualized veins along the falx.

Commonly there may be marked shift of the internal cerebral vein in the antero-posterior projection with a normal pattern of the deep cerebral veins in the lateral projection.

In stereoscopic antero-posterior projections the strio-thalamic and other tributory veins draining into the internal cerebral vein and coursing over the superior aspect of the thalamus provide a definitely recognizable normal pattern which may be distorted in space-taking lesions and in hydrocephalus.

An attempt at localization of the tumor in the a.p. view is warranted

only if there is a marked discrepancy between the degree of displacement of the anterior cerebral artery and that of the internal cerebral vein. We believe that study of the stereoscopic a.p. projections is the most accurate way to assess the degree of lateral displacement of the internal cerebral vein. Equal displacement of the anterior cerebral artery and the internal cerebral vein could be produced by a small hemispheric lesion equidistant from the two or by diffuse changes such as edema, a diffuse glioma or multiple metastatic foci (Fig. 4).

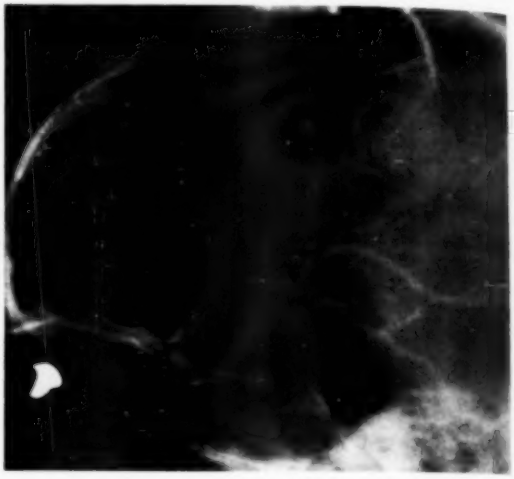


Fig. 5. Lateral view, venous phase. False venous angle is indicated by F. V. A. as opposed to true venous angle (T. V. A.).

The pineal gland is not as vulnerable to displacement by space-taking lesions as is the internal cerebral vein, probably due to shielding by the falx and tentorium. The internal cerebral vein and the anterior cerebral artery are apt to be displaced more than the pineal regardless of the position of the lesion.

We feel that it should be emphasized that only very rarely does the lateral phlebogram in itself provide evidence leading to the diagnosis of an expanding intracranial lesion. The lateral phlebogram is frequently of localizing value and commonly provides evidence confirming the arteriographic findings.

Others have described, and we have reported in detail elsewhere, the tributaries of the internal cerebral vein, other than the strio-thalamic, which can simulate the junction of the latter vein with the internal cerebral vein, a point referred to by RICHTER as the 'venous angle of the brain'. We have estimated from our studies that differentiation of the true from the 'false' venous angle can give rise to some difficulty in roughly 10 % of cases. The availability of a sequence of several stereoscopic biplane exposures in the venous phase has unquestionably aided us in the differentiation of the actual junction of the striothalamic vein with the internal cerebral vein from variants which may simulate this junction (Fig. 5).

SUMMARY

A method of simultaneous biplane stereoscopic cerebral angiography has been presented. The unique features of stereoscopy and of simultaneous biplane exposures are discussed separately in terms of the advantages provided in identifying individual vessels, especially the deep cerebral veins, tumor circulation and the collateral circulation in thrombosis. Limitations of the method are also described.

ZUSAMMENFASSUNG

Eine Methodik für gleichzeitige biplane stereoskopische cerebrale Angiographie is vorgelegt worden. Die besonderen Kennzeichen der Stereoskopie und der simultanen biplanen Exponierungen werden unter Bezugnahme auf die Vorteile für die Identifizierung einzelner Gefässe, besonders der tiefen cerebralen Venen besprochen, bei der Tumorlokalisation und dem Kollateralkreislaufes bei der Thrombose. Die Begrenzungen der Methode werden ebenfalls beschrieben.

RÉSUMÉ

Les auteurs présentent une méthode d'angiographie cérébrale stéréoscopique simultanée en deux projections perpendiculaires. Les caractéristiques propres de la stéréoscopie et des projections perpendiculaires simultanées sont étudiées séparément du point de vue des avantages qu'elles apportent pour l'identification des différents vaisseaux, en particulier les veines cérébrales profondes, la circulation des tumeurs et la circulation collatérale des thromboses. Les limites de cette méthode sont aussi étudiées.

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NOUVELLE METHODE D'ANGIOGRAPHIE CEREBRALE SIMULTANEE TOTALE PAR INJECTION INTRAVEINEUSE RAPIDE

par

P. Viallet, L. Sendra, L. Chevrot, P. Combe, P. Descuns et *P. Aubry*

Notre méthode d'angiocardiopneumographie nous permettait depuis quelques mois d'individualiser l'aorte et ses branches avec une grande certitude. En janvier 1955, nous avons pensé qu'il serait possible de lire les vaisseaux cérébraux après une injection intraveineuse et nous avons énoncé la proposition suivante:

«Dans l'état actuel des progrès de l'appareillage radiologique et de la pharmacopée, une injection intraveineuse rapide d'un produit de contraste iodé, puis de sérum physiologique, permet sans le moindre risque pour le malade, une exploration de qualité, physiologique, de la totalité ou d'une fraction de la grande circulation.»

Notre méthode qui démontre la proposition précédente est l'aboutissement d'une série de perfectionnements intéressant les opérateurs, les malades, le choix de la voie d'apport, le matériel d'injection, la préparation des produits, la vitesse d'injection de ces derniers et enfin l'appareillage radiologique.

Le malade subit une prémédication, variable avec les cas particuliers et son anxiété, du type de la médication pré-anesthésique utilisant les barbituriques et les antihistaminiques. Nos contre-indications sont rares; ce sont les insuffisances organiques graves et surtout les cardiopathies droites. Le malade est soigneusement «testé» pour éviter un éventuel accident d'intolérance au produit iodé. Cette exploration est applicable à un pourcentage très élevé des malades et à tous les âges. La voie d'injection est toujours intraveineuse. La dénudation est indispensable, elle peut se faire au pli du coude ou au niveau de la jugulaire externe; la voie fémorale est évidemment possible. C'est la notion du plus gros calibre veineux abordable par dénudation facile qui impose le choix du point d'injection.

Notre matériel d'injection est «l'injecteur simple de Sendra» composé: d'une seringue de 200 ou 300 cm³ mise en place sur un support bipode qui la maintient verticalement; d'un tuyau de nylon transparent très résistant permettant d'aspirer avant d'injecter et de voir le sang remonter vers la seringue; d'un trocart de très gros calibre; aussi gros que peut l'admettre la veine dans laquelle se fait l'injection; il a entre 3 et 7 mm de calibre intérieur; ce sont ses dimensions qui imposent la dénudation.

L'injection doit être rapide, réalisant une hyperpression dans le système veineux, car le produit opacifiant doit arriver non dilué au cœur droit. Nous poussons donc en une ou deux secondes, à la main, 1 à 1.5 cm³ par kg de poids des nouveaux opacifiants triodés à 70 %, soit 60 à 100 cc chez l'adulte.

Il est capital, pour rincer le système veineux parcouru par le produit jusqu'au cœur droit, d'injecter immédiatement après le produit iodé, une quantité sensiblement égale de sérum physiologique, soit 60 à 100 cc, au total 120 à 200 cc de liquide. Ce sérum est placé dans la seringue au-dessus du produit iodé et surnage par différence de densité.

Nous ne décrirons pas les appareillages radiologiques. Ils doivent permettre d'obtenir des clichés dans les temps les plus rapides donnés par la technique actuelle. On doit disposer d'un sériographe à débit rapide. Il est important de réaliser le plus grand nombre possible de films. Pour notre part, nous les obtenons sur un appareil sériographique de notre conception, réalisé à Alger et débitant 12 cassettes de format 30 cm × 40 cm en neuf secondes.

Cette méthode d'injection intraveineuse rapide, par gros trocart, de produit de contraste iodé, puis de sérum, permet l'étude radiologique de la petite mais aussi de la grande circulation. C'est la technique que, depuis plusieurs années, nous avons employée pour réaliser sans incident plusieurs centaines d'angiocardiopneumographies ou d'explorations périphériques. Telle quelle, cette exploration est facile et sans danger. Elle ne nécessite pas d'anesthésie. Plus facile que l'injection par voie intra-artérielle, elle permet mieux l'association avec les autres techniques d'obtention de contraste (encéphalographie gazeuse par exemple), et avec les méthodes mécaniques ou pharmacodynamiques modifiant l'état vasculaire (compression, médications vasodilatatrices.)

Il est certain que depuis longtemps nous avions des artériographies cérébrales à l'état virtuel. Nous avons cette année seulement pensé à placer des films sous la tête de nos malades. Nous ne sommes d'ailleurs pas très fiers d'avoir mis si longtemps à comprendre ce fait. Ainsi par une seule injection intraveineuse, nous évitons la ponction ou la dénudation carotienne ou vertébrale, les 3 injections intra-artérielles nécessaires classiquement pour opacifier tous les vaisseaux cérébraux, et les difficultés à réaliser certaines incidences du fait de la présence de l'aiguille de ponction dans l'artère.

Nous replaçons l'angioencéphalographie dans les mains du radiologiste ou tout au moins d'une équipe radio-médicale.

Anatomiquement, nous obtenons images qui nous montrent une artériographie totale simultanée des carotides, des vertébrales et de leurs branches encéphaliques (fig. 1), avec possibilité de comparer sur le plan

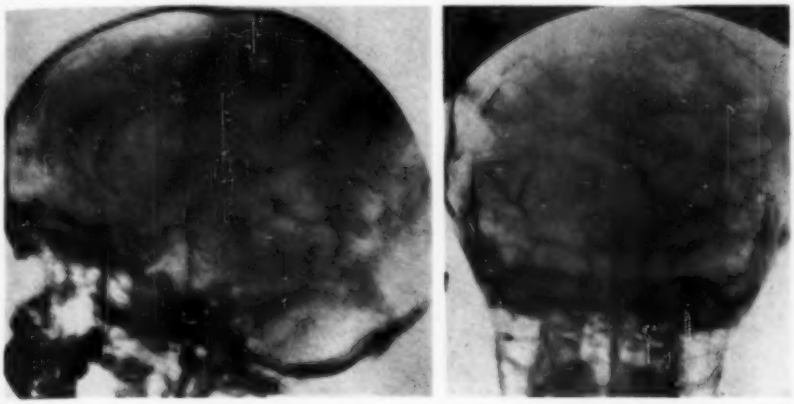


Fig. 1. Artériographie totale simultanée des carotides, des vertébrales et de leurs branches encéphaliques; possibilité de comparer les artères droites et gauches, ainsi que les veines.

statique et morphologique les artères droites et gauches, ainsi que les veines (fig. 2). Les phlébographies totales que nous obtenons sont probablement moins capricieuses que celles réalisées par voie mono-artérielle ou transosseuse.

L'angiographie peut-être suivie depuis sa source cardio-aortique, voir fig. 3 d'un adulte de 25 ans présentant un syndrome clinique ophtalmologique.

Physiologiquement, nous supprimons l'agression artérielle évitant ainsi les spasmes si fréquents, en particulier au niveau de la vertébrale. Notre exploration est essentiellement fonctionnelle. Le produit opaque après avoir transité par le coeur droit et le poumon est pratiquement injecté dans le système artériel par le ventricule gauche.

Nous avons la possibilité d'apprécier les vitesses circulatoires réelles.

Nos premières conclusions sont les suivantes. Le sang arrive dans les artères du cou et de l'encéphale entre la 5ème et la 15ème seconde après la fin de l'injection. Ce transit du produit opaque depuis la veine périphérique d'injection jusqu'aux carotides et aux vertébrales est ralenti chez le vieillard, chez les scléreux pulmonaires, et chez les insuffisants cardiaques. Nous notons une simultanéité d'opacification des branches de la carotide interne et de la carotide externe.

Cependant, les vaisseaux encéphaliques ont un calibre supérieur à celui des branches terminales de la carotide externe. Le plus souvent, la concentration est insuffisante pour opacifier la méningée moyenne, la temporale superficielle et les branches terminales de l'occipitale. Ces

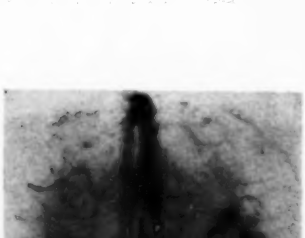


Fig. 2. Phlébographie totale.

Fig. 3. Artériographie normale du cou et de la tête.

Fig. 3.

faits montrent, comme le pensait Egas Moniz, la primauté circulatoire au niveau du cerveau sinon dans le temps tout au moins dans le volume de l'ondée sanguine.

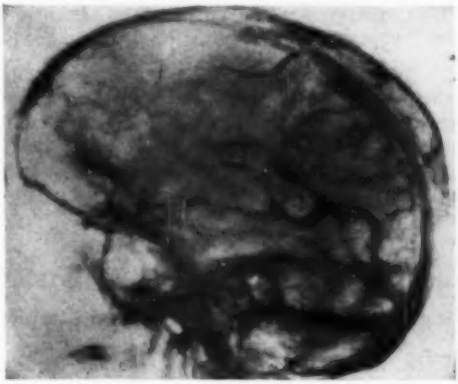
Dans l'encéphale, notre méthode prouve que l'opacification des siphons carotidiens et du tronc basilaire est simultanée. Par ailleurs, après Egas Moniz, Krayenbühl et Richter, nous constatons que le temps d'opacification artériel est de l'ordre de 3 secondes et le temps d'opacification veineux de l'ordre de 9 secondes environ avec un temps parenchymateux intermédiaire de 1 seconde environ. Contrairement aux constatations classiques, il nous semble que les veines centrales, affluents de l'ampoule de Galien, s'opacifient sensiblement dans le même temps que les veines superficielles. D'ailleurs les opacifications du système de Galien sont relativement meilleures avec notre méthode (fig. 4) que lors des injections monocarotidiennes; ceci ne fait que confirmer l'importance du tronc basilaire dans la circulation encéphalique.

De la même façon, l'effacement du produit iodé se fait d'abord au niveau des veines périphériques superficielles et profondes, ensuite au niveau des sinus; les sinus latéraux étant les derniers visibles. Ce fait est logique, conforme au circuit suivi par le sang. Il ne semble cependant pas avoir encore été souligné de façon précise.

Nous avons dit que toutes les incidences étaient possibles. En vérité,

la pression physiologique du ventricule gauche est minime, et de ce fait nous devons tenir compte attentivement des lois de l'hémodynamique, certaines modifications de la statique étant susceptibles de jouer de façon importante sur les opacifications vasculaires.

L'incidence de profil, si elle est réalisée avec une rotation trop marquée du cou, a pour conséquence une non-opacification de l'artère cérébrale du côté opposé à la rotation.



Fip. 4. Les veines centrales, affluents de l'ampoule de Galien, s'opacifient dans le même temps que les veines superficielles.

Au début de l'utilisation de notre méthode, nous avons réalisé un assez grand nombre d'examens en incidence de WORMS BRETTON: la flexion trop marquée de la tête sur le thorax entraîne manifestement un ralentissement de la circulation dans les 2 carotides avec, par là même, une moins bonne opacification.

Sur le plan physiopathologique, nous avons pu apprécier en plus des modifications des temps circulatoires globaux: des décalages relatifs dans le temps entre les deux sylviennes (l'une d'entre elles s'opacifiant avant l'autre), et des mécanismes de vicariance. Par exemple, dans une trombose de la carotide interne, la possibilité de voir toutes les artères cervicales, à destinée encéphalique, et de les comparer, nous a permis d'apprécier avec objectivité une suppléance circulatoire se caractérisant par une hypertrophie de la vertébrale homologue.

RÉSUMÉ

Dans l'état actuel des progrès de l'appareillage radiologique et de la pharmacopée, une injection intraveineuse rapide d'un produit de contraste iodé, puis de sérum physiologique, permet sans le moindre risque pour le malade, une exploration de qualité, physiologique, de la totalité ou d'une fraction de la grande circulation et en particulier de la circulation cérébrale.

SUMMARY

Roentgen apparatus of today in combination with modern pharmacopedics permit a detailed physiologic exploration of the whole or part of the circulatory system, particularly the cerebral portion. The rapid intravenous injection of an iodised medium followed by the administration of physiologic serum is employed and constitutes little risk for the subject.

ZUSAMMENFASSUNG

Nach dem heutigem Stand der Arzneimittelindustrie und dem technischen Fortschritt im Aparatenbau (Roentgen) ist es möglich, durch eine intravenöse Schnelleinspritzung eines Iodkontrastmittels und anschliessend einer physiologischen Seruminjektion, ohne den geringsten Schaden für den Kranken zu verursachen, eine gründliche und genaue physiologische Erforschung des gesammten Blutkreislaufes zu erzielen. Besonders Teilgebiete der Zirkulation, wie z. B. die Durchblutung des Gehirns werden klar und einfach sichtbargemacht.

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CLINIQUE MÉDICALE INFANTILE (PROF. CH. SARROUY) ET CLINIQUE CHIRURGICALE INFANTILE (PROF. P. LOMBARD), HÔPITAUX CIVILS D'ALGER, ALGÉRIE

L'UTILISATION DE L'ANGIOGRAPHIE CEREBRALE TOTALE SIMULTANEE, PAR VOIE INTRA-VEINEUSE CHEZ L'ENFANT

par

Ch. Pheline, P. Viallet, L. Sendra, P. Combe, L. Chevrot, et *P. Aubry*

L'angiographie totale par voie intra-veineuse a pris naissance dans un Hôpital d'enfants; circonstance heureuse qui nous a permis d'apprécier les avantages de la méthode dans ce domaine particulier. Toute artériographie chez l'enfant était, jusqu'à présent, une entreprise difficile, presque impossible chez le nourrisson sans dénudation artérielle, ce qui réduisait nos champs d'exploration en pathologie infantile.

Par une simple dénudation veineuse avec une injection unique massive de produit de contraste tri-iodé, on peut actuellement obtenir une opacification complète de tout le réseau vasculaire cérébral, quelque soit l'âge de l'enfant. Telle est la simplicité et l'inocuité de la méthode que nous n'avons pas hésité à la faire subir aux 35 encéphalopathes qui ont été hospitalisés chez nous depuis le début de l'année. Leur âge s'étageait entre quelques mois et 14 ans.

Une étude systématique portant sur un aussi petit nombre de malades, ne peut nous permettre de tirer des conclusions valables, mais seulement d'offrir les remarques que nous avons pu faire en cours d'étude.

Tout d'abord, il s'agit d'une méthode aussi pratique qu'une urographie intra-veineuse, facile d'exécution, rapide, puisque 8 à 10 peuvent facilement être exécutés d'affilée par la même équipe en une matinée. Beaucoup de nos malades non hospitalisés, viennent au sanatorium d'enfants subir leur exploration et repartent une à deux heures après par leurs propres moyens. Nous n'utilisons jamais l'anesthésie générale; une prémédication à base de barbituriques suffit à calmer l'enfant de

façon satisfaisante. Néanmoins, une légère agitation est habituelle pendant le temps capillaire. Elle correspond sans doute à la courte phase d'anoxie cérébrale totale.

Nous n'avons eu à déplorer aucun accident, tout au plus quelques quintes de toux, ou des vomissements, en fin d'injection, ou encore une réaction érythémateuse passagère. Nous injections 1.5 à 2 cc par kg de poids. Une opacification vasculaire satisfaisante est toujours obtenue; nous avons même remarqué qu'elle est habituellement meilleure que chez l'adulte en raison d'une tolérance plus grande au produit, et d'une circulation pulmonaire plus rapide. Un test de sensibilité à l'iode est pratiqué avant l'exploration. Nous ne tenterions pas ce procédé d'angiographie dans les cas d'atteinte cardiaque ou rénale grave.

Le progrès essentiel apporté par cette méthode tient à la possibilité de comparaison, puisque sur un même cliché, dans des conditions absolument identiques, on voit s'opacifier simultanément les territoires symétriques. Ainsi apparaissent au premier coup d'œil les altérations morphologiques, structurales, ou topographiques, et, en comparant les différents clichés de la série, les altérations dynamiques de la circulation cérébrale, puisque, alors que normalement il y a une symétrie et synchronie d'opacification des différents troncs et de leurs branches, dans certains cas cette symétrie, et cette synchronie, sont perturbées au niveau de territoires plus ou moins étendus.

Résultats

1°) *Les atrophies cérébrales.* Une opinion dénie à l'angiographie la possibilité de montrer une atrophie cérébrale. Nous avons pu, en réalité, sur les seules images angiographiques affirmer le diagnostic d'atrophie. Sans contester la valeur de l'étude pneumographique, nous pensons que l'angiographie peut remplacer toute étude aérique lorsqu'on n'a besoin que de confirmer un diagnostic et susciter une encéphalographie gazeuse si des précisions topographiques sont nécessaires. Chez nos deux malades atteints d'atrophie corticale diffuse, les artères corticales se voyaient en coupe sur le cliché de face, à une certaine distance de la voûte du crâne, et les encéphalographies gazeuses ont confirmé par la suite la profondeur des sillons de la convexité.

Nos cinq atrophies hémisphériques unilatérales nous ont montré l'image typique d'attraction de la cérébrale antérieure, vers le côté malade, le relèvement du groupe sylvien atteint et, à la phase veineuse, l'attraction de la veine de Galien et du sinus droit vers l'hémisphère atrophique.

Dans notre série, se trouvait également une atrophie cérébelleuse, secondaire à une toxoplasmose, dans laquelle la seule anomalie visible était un très fort déplacement du sinus latéral.

2°) Le diagnostic angiographique d'*hydrocéphalie* est facile. Les artères semblent anormalement grêles, étirées; les collatérales sont pincées en un pinceau distal; cet aspect est particulièrement apparent sur le cliché de face, où le ventricule dilaté repousse les branches de la sylvienne dans le quart externe de la boîte crânienne. La cérébrale postérieure n'est pas sensiblement modifiée dans sa topographie, mais l'impression de vacuité centrale évoque fortement le diagnostic d'hydrocéphalie.

Nos cinq hydrocéphalies communiquantes, qui étaient assez frustres, montraient cette image typique à des degrés variés. Elle se marquait à un degré beaucoup plus important dans nos deux hydrocéphalies obstructives.

3°) Notre méthode nous a permis de mettre en évidence les *ralentissements circulatoires* soit généralisés, soit localisés. Chez trois malades, il existait un ralentissement diffus du temps artériel, puisque celui-ci se poursuivait sur 8 secondes et plus, sans que la moindre opacification veineuse intervienne. Ce ralentissement était généralisé à tous les territoires artériels et, chez ces trois malades, un syndrome clinique bien défini était représenté. Il se composait de retards intellectuels, d'épisodes de mal comitial, de périodes comateuses inexpliquées, avec des signes focaux fugitifs. Aucun autre examen complémentaire n'avait permis de fournir d'explication à ces syndromes. Nous pensons qu'il s'agit là d'une affection nouvelle, qu'il était impossible de décrire, jusqu'à ce qu'une méthode physiologique ait pu la mettre en évidence.

Dans deux cas il existait un ralentissement partiel de la circulation artérielle localisé à un territoire sylvien particulier. Ici, il nous est assez difficile de fournir une explication, s'agit-il d'un spasme, d'un rétrécissement localisé, avec phénomène de vicariance, ou d'une fistule artério-veineuse peu visible sur les clichés.

4°) Nous avons fait subir notre méthode d'angiographie intra-veineuse à trois petits malades atteints de *dysostose craniofaciale*. Ceci est un exemple des domaines nouveaux accessibles à l'angiographie, puisque chez ces enfants infirmes, on hésite actuellement à pratiquer un examen complémentaire traumatisant, alors qu'il est indispensable de connaître la physiologie de la circulation artérielle chez ces malades, en particulier, lorsqu'il existe une dégradation progressive des fonctions visuelles et mentales et que l'on suspecte une hypertension intra-crânienne. De même, chez les épileptiques, les traumatisés crâniens, et lorsqu'on soupçonne un trouble fonctionnel circulatoire ou une malformation vasculaire, on pourra beaucoup plus facilement qu'avant faire une angiographie qui permettra au prix d'un traumatisme minime de poser un diagnostic.

RÉSUMÉ

Une utilisation systématique de l'angiographie intra-veineuse dans le domaine de la neuropathologie infantile (35 cas) a montré: que ce procédé était d'application très facile; qu'il était sans danger; qu'il donnait des renseignements que l'angiographie directe ne peut donner (comparaison des deux côtés, insuffisances vasculaires fonctionnelles). Il semble que ce soit chez l'enfant que la méthode trouve sa meilleure indication.

SUMMARY

The routine employment of intraveinous angiography in 35 cases of neuropathologic conditions in children has shown that the procedure is easy of application and without risks, and that it affords information not given by direct angiography (comparison between the two sides, functional vascular insufficiency). It seems that it is particularly in children that the method can be applied to the best advantage.

ZUSAMMENFASSUNG

Die systematische Anwendung der intravenösen Angiographie in 35 Fällen mit neuropathologischen Erkrankungen des Kindesalters zeigte, dass die Methode leicht auszuführen ist, dass sie gefahrlos ist und dass sie Aufschlüsse bietet, welche die direkte Angiographie nicht geben kann (Vergleich der beiden Seiten, funktionelle Gefässinsuffizienzen). Die Methode scheint am besten für die Untersuchung von Kindern geeignet zu sein.

DISCUSSION OF ARTERIOGRAPHY

G. Ruggiero (Paris):

Sans vouloir nullement préjuger de l'avenir d'une technique nouvelle, nous croyons qu'il n'existe pas actuellement de raisons pour lesquelles la technique de l'angiographie cérébrale par voie intraveineuse puisse être préférée à l'artériographie carotidienne ou vertébrale percutanée.

Contrairement à ce que beaucoup de gens, d'expérience limitée, affirment, l'angiographie cérébrale n'est pas un procédé sans danger et les risques sont surtout dûs à la quantité et à la concentration du contraste injecté. Il est nécessaire pour l'angiographie intraveineuse d'injecter environ 70 cc de contraste à 70 %. Or, l'évolution naturelle et logique de l'angiographie cérébrale est de limiter au maximum la quantité de contraste injecté. Dans l'artériographie percutanée on n'injecte en général pas plus de 10 cc de contraste pour chaque série de clichés. Dans les derniers temps on a eu de plus en plus tendance à diminuer encore la quantité de contraste. D'après les recherches faites par ODÉN en Suède, et CALABRÒ dans notre service, il apparaît que 5 à 6 cc de contraste triodé à 30 %, ou même 2 à 3 cc à 50 %, sont suffisants. Il est évident que l'emploi de quantités de contraste si limitées rend plus difficile la technique car il est nécessaire, dans le cas de l'artériographie carotidienne par exemple, de ponctionner séparément la carotide interne et la carotide externe. D'autre part la visualisation séparée des différentes circulations cérébrales (la circulation de la carotide interne et de la carotide externe des deux côtés et des vertébrales) facilite au lieu de compliquer la lecture des images, par conséquent rend plus aisé le diagnostic.

Sauf peut-être pour la recherche d'anévrysmes sacculaires, nous sommes incapables maintenant de voir dans quelles conditions la visualisation simultanée de tous les vaisseaux cérébraux peut être utile, mais même dans ces cas il ne faut pas oublier les dangers que pourrait comporter le passage de contraste dans tout le système artériel en même temps. Chez un sujet porteur d'anévrysme, et qui a souffert plus ou moins récemment d'une hémorragie sous-arachnoïdienne, l'artériographie peut aggraver un état spastique des artères cérébrales, et il n'est pas besoin,

je crois, d'insister sur le danger que ce fait se produise contemporainement dans tous les territoires du cerveau.

Au point de vue strictement technique, l'angiographie par voie intraveineuse présuppose la dénudation de la veine, ce qui représente une certaine difficulté technique qui compense largement les rares cas dans lesquels la ponction directe de l'artère présente des difficultés.

Le Dr. VIALLET nous dit que sa méthode remet l'artériographie dans les mains du radiologiste. Mais elle y est déjà! Les progrès, dans le domaine de l'artériographie cérébrale, ont été réalisés dans les centres où cet examen, y compris la ponction de l'artère, est fait par les radiologistes. D'ailleurs, dans le laboratoire de Radiodiagnostic du Centre Neurochirurgical de l'Hôpital Ste-Anne, depuis que nous en avons la responsabilité, plusieurs centaines d'artériographies ont été faites entièrement par les radiologistes. Au contraire il me semble que la technique proposée par le Dr. VIALLET peut avoir l'effet opposé, c'est-à-dire inciter ceux qui ne sont pas compétents à faire les angiographies cérébrales, avec tout le danger qu'une mauvaise interprétation peut comporter. On assiste déjà assez aux malheureuses conséquences de la généralisation de techniques qui devraient être le seul apanage de centres spécialisés.

FROM THE ROENTGEN DEPARTMENT (DIRECTOR: PROF. ERIK LINDGREN),
SERAFIMERLASARETTET, STOCKHOLM, SWEDEN

RAPID SERIAL ANGIOGRAPHY

by

Torgny Greitz

Rapid serial angiography has been used in neuroradiologic diagnosis at Serafimerlasarettet since 1952. Our equipment has been constructed with special regard to the requirements of cerebral angiography, and was described at the Third Symposium Neuroradiologicum by SJÖGREN and FREDZELL. It consists essentially of a cut-film changer with a maximum speed of six films per second, and a magazine holding 30 frames. Within the limits indicated by these data, there is complete freedom of program selection.

The material in this study consists of 120 cases. In order to facilitate exact comparison between the different examinations, these have been carried out with a uniform technique: 2 films/sec for the first 5 seconds, and then 1 film/sec for 10 seconds. This does not mean, however, that such a program is the most suitable in all cases.

Four ml Triurol 50 %, a Swedish contrast medium of the same composition as Urokon, has been employed. The beginning and end of the injection and the exposures have been recorded on an ECG strip. In order that the injection may be correctly recorded, it is necessary that the connection between the needle and the syringe is non-elastic and of small volume. A fine plastic tube has therefore been used.

Judging by the recent literature, the circulation in the vessels of the brain has been studied by means of serial angiography at several hospitals. The author has, however, not been able to find a uniform definition of the arterial phase, venous phase, or circulation time. The circulation time has by most authors been considered to be the time elapsing between the beginning of the arterial phase and the end of the venous phase. This time is, however, to a large extent dependent on the amount of contrast medium that has been injected and the time required for the injection. The longer the injection time, and the larger the amount of contrast medium, the longer will it take before the contrast medium has left the veins.

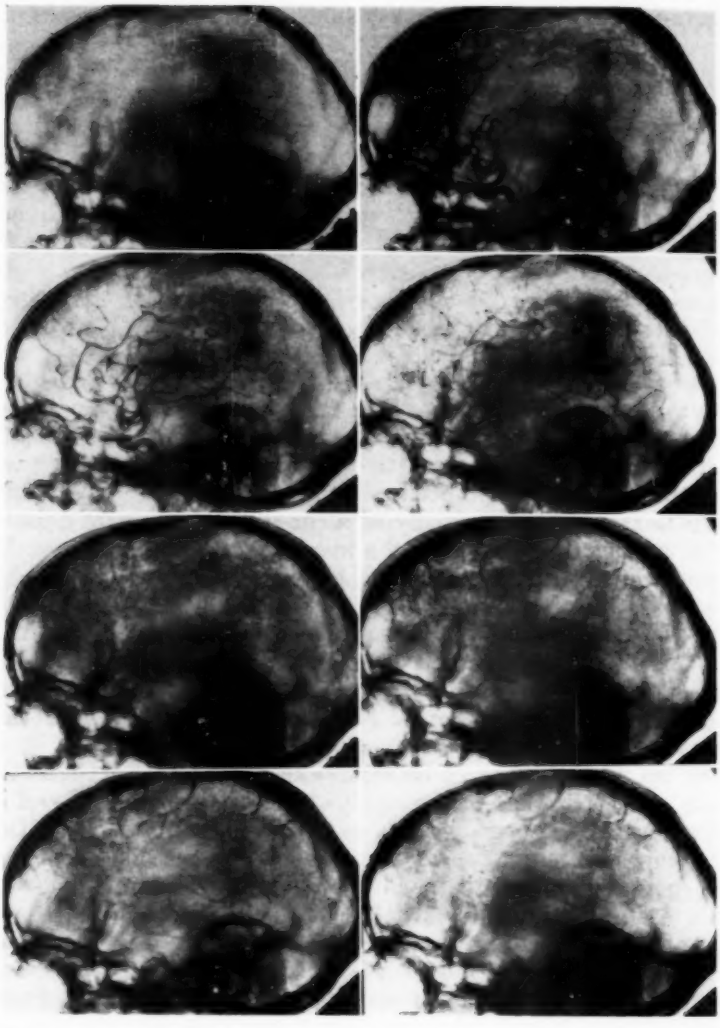

Fig. 1. Normal case. 0.5 sec intervals between films in two upper rows, 1 sec between others. Arteries fill more rapidly frontally than occipitally. Frontal veins and veins of Sylvian fissure achieve maximum filling earlier than more posterior veins. Maximum filling of carotid siphon recorded in top right view. Maximum filling of parietal veins is considered to fall between bottom left and preceding film. Time difference between these maximum points, *i. e.* circulation time, as recorded on ECG strip, is 4.4 sec.

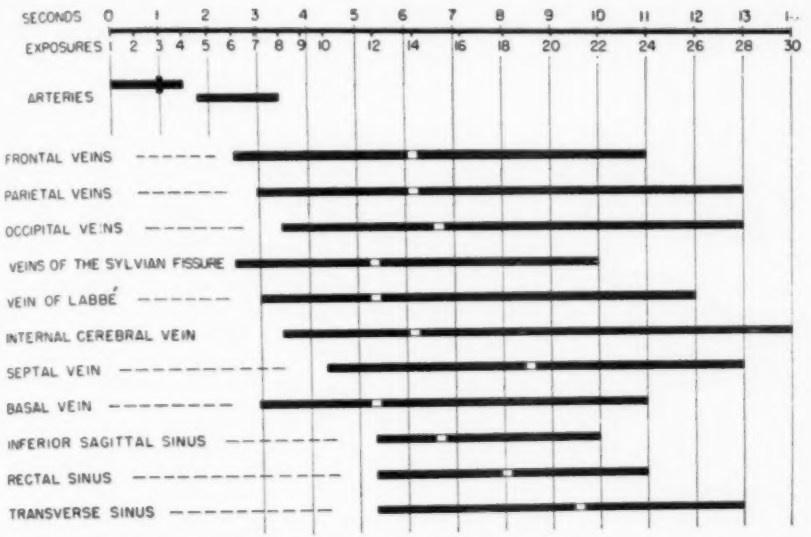
SECONDS 0 1 2 3 4 5 6 7 8 9 10 11 12 13
EXPOSURES 1 2 3 4 5 6 7 8 9 10 12 14 16 18 20 22 24 26 28 30
ARTERIES
FRONTAL VEINS
PARIETAL VEINS
OCCIPITAL VEINS
VEINS OF THE SYLVIAN FISSURE
VEIN OF LABBÉ
INTERNAL CEREBRAL VEIN
SEPTAL VEIN
BASAL VEIN
INFERIOR SAGITTAL SINUS
RECTAL SINUS
TRANSVERSE SINUS

Diagram 1. Sequence of contrast filling of different veins in normal case. Lines broken at point of maximum filling, *i. e.* the transition between filling and emptying phases. This point, determined for parietal veins, roughly coincides with the average for cerebral veins.

By recording the movement of the head of column of contrast medium from the carotid siphon to the smallest arteries that are radiologically observable, it is possible to measure the time required for the arteries to fill. This period will be termed the arterial filling phase. In a similar manner the time required for the arteries to empty has been determined. This period is called the arterial emptying phase.

By means of rapid serial angiography it is possible to determine at which point maximum contrast filling of the veins occurs; beyond this point the veins begin to empty. Thus, like in the arteries, there is a venous filling phase and a venous emptying phase. The transition between the filling and emptying phases does not occur quite simultaneously in different parts of the brain (Fig. 1). For instance, in most cases it occurs earlier frontally than occipitally. These variations are, however, considerably smaller than those occurring at the end of the venous phase. It is, furthermore, impossible to determine the termination of emptying with any degree of exactness, since the contrast filling seems to decrease in an ever-diminishing fashion, or asymptotically.

The material has been examined with regard to the difference in phase between the contrast filling of different veins. The filling and

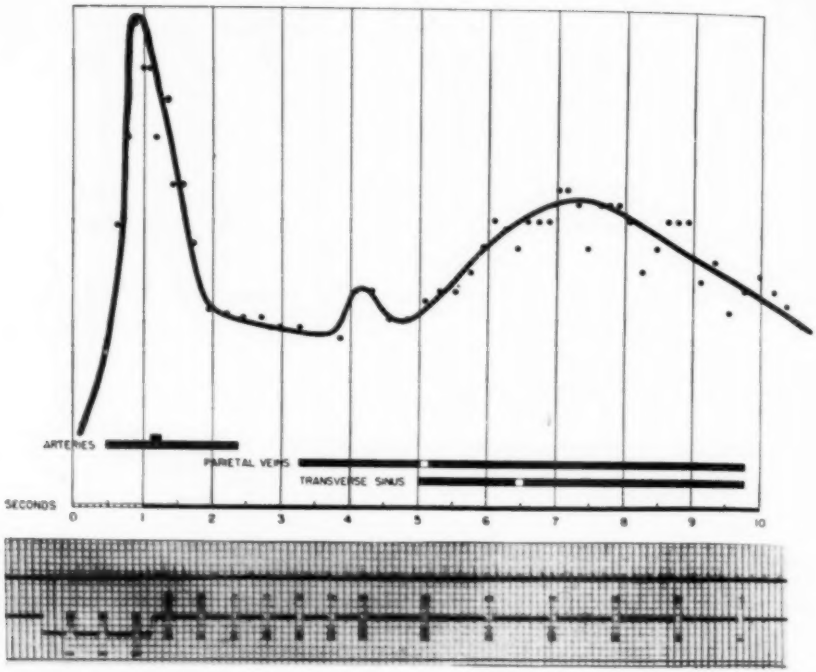

Diagram 2. Experiment with blend of contrast medium and isotope. During angiography impulses from carotid artery and jugular vein are absorbed by detector, placed in front of mastoid process. Injection, roentgen exposures (bottom), and every hundredth impulse from scintillation counter, are recorded on ECG strip. If counting rate is plotted against time, a curve with two main peaks is obtained. Peak of arterial phase coincides with maximum filling of carotid siphon; peak of venous comes immediately after maximum filling of transverse sinus.

emptying phases have been recorded for a large number of veins: the frontal, parietal and occipital veins, the veins of the Sylvian fissure, the vein of Labbé, the central veins, and the dural sinuses (Diagr. 1). Maximum contrast density has sometimes been recorded in two films; the maximum point has then been considered to fall between these films. This study has shown that the superficial frontal veins and the veins of the Sylvian fissure generally are the first to fill. Most often they are also the first to commence to empty. The septal vein is conspicuously late in beginning to fill. The emptying of this vein starts as much as two seconds later than in most others. Judging from this study, the superficial parietal veins seem to constitute a representative average for the cerebral veins.

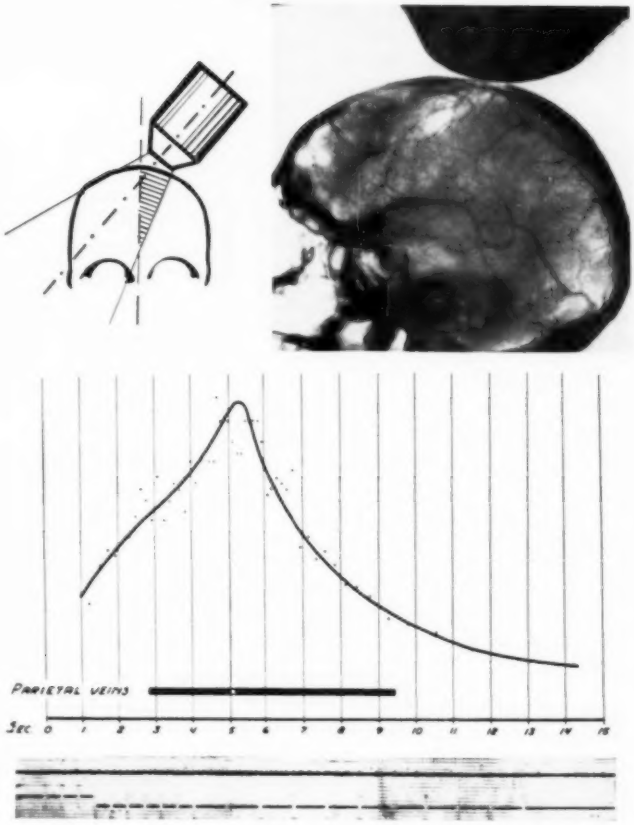

Diagram 3. Impulses recorded above a group of parietal veins, following injection of contrast medium with isotope. Detector absorbs impulses only from small sector highest on convexity. Film 11, of maximum venous filling, corresponds to peak of isotope curve.

As a rule, maximum filling in these occurs at the same time as in the internal cerebral vein.

The circulation times have also been determined by means of radioactive isotopes, and the results have been compared with the times computed in rapid serial angiography. We have used either radioactive sodium or radioactive iodine, and have not been able to find any difference between these two. If radioactive iodine is used, the thyroid gland must be blocked in advance with iodine. Lugol's solution has been employed for this purpose.

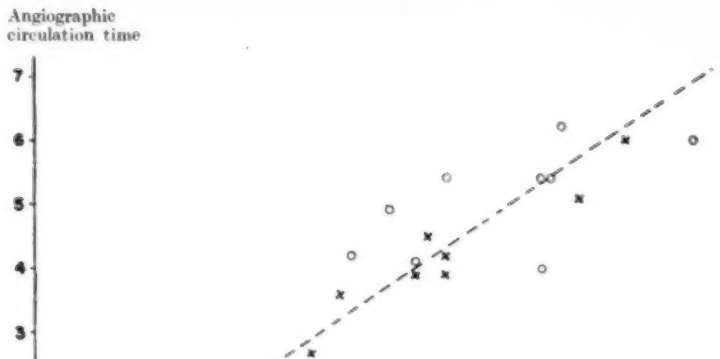

Diagram 4. Correlation between 'angiographic' and 'isotopic' circulation times. Broken line indicates ratio as 2 : 3. Crosses represent experiments with blend of contrast medium and isotope; circles represent the experiments, in which the circulation time was first determined by angiography and later by isotopes.

In 8 experiments, contrast medium and isotope have been carefully blended and injected together. Immediately in front of the mastoid process, the internal carotid artery and the bulb of the jugular vein lie very close together. By aiming a well-shielded and well-collimated detector in a latero-medial direction towards this point, the circulation may be timed by means of both isotopes and angiography simultaneously. Every hundredth impulse has been recorded on the same ECG strip as the roentgen exposures. Through inverting the distances between the recorded impulses, curves with two peaks have been obtained (Diagr. 2). The background radiation is somewhat increased by the roentgen exposures, but to such a slight extent that it has no effect on the appearance of the curves.

In these 8 experiments, the peak of the arterial phase coincided in time with maximum contrast filling of the carotid siphon. The peak of the venous phase came immediately after maximum contrast filling of the transverse sinus. The time difference was generally somewhat less than one second. The transverse sinus was well filled with contrast me-

dium in these eight experiments and the point of maximum filling could be definitely determined which, however, is not always possible. On the other hand, it is always possible to observe when the parietal veins begin to empty.

Diagr. 3. illustrates an experiment with a blend of contrast medium and isotope in which the detector was placed above a group of parietal veins and aimed towards the contralateral side in such a manner that it absorbed impulses only from a very small sector lying highest up on the convexity. Three different examiners independently reached the conclusion that the parietal veins achieved maximum filling in the film reproduced, which corresponded to the peak of the isotope curve. It is thus possible, and it also seems most practical, to define the circulation time as the time interval between maximum filling of the carotid siphon and maximum filling of the parietal veins.

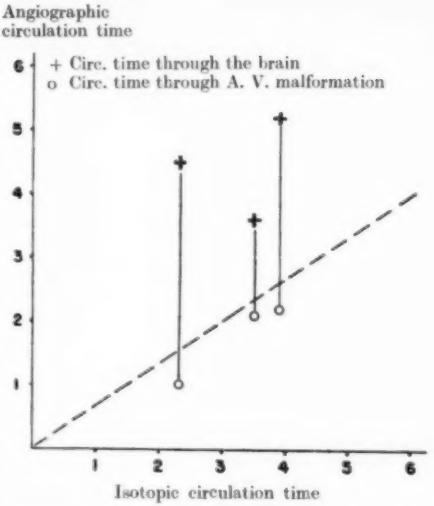

Diagram 5. Correlation between 'angiographic' and 'isotopic' circulation times in three cases of arterio-venous malformations. Broken line same as in diagram 4. 'Angiographic' circulation time determined both for brain and for malformation.

In another series of nine experiments the circulation time was first determined by means of angiography and later on by means of isotopes. The correlation between the angiographic and isotopic circulation times, in both the series mentioned, is indicated in Diagr. 4. Generally speaking, the circulation time determined by isotopes is about 50 per cent longer. This is due to the fact that the circulation time in the isotope investigations is lengthened by the time corresponding to the passage from the parietal veins to the jugular vein. The rate of flow in the sinus may thus be computed. It is about 10 centimetres per second.

In the first series of eight experiments, which were made with a blend of contrast medium and isotope, the dispersion was small but in the second it seemed to be larger. This fact could probably be accounted for by variations in the patients, since the values in the second series were distributed on both sides of those of the first.

In cases of arteriovenous malformations two circuits may be said to exist, one through the normal vessels of the brain and the other through

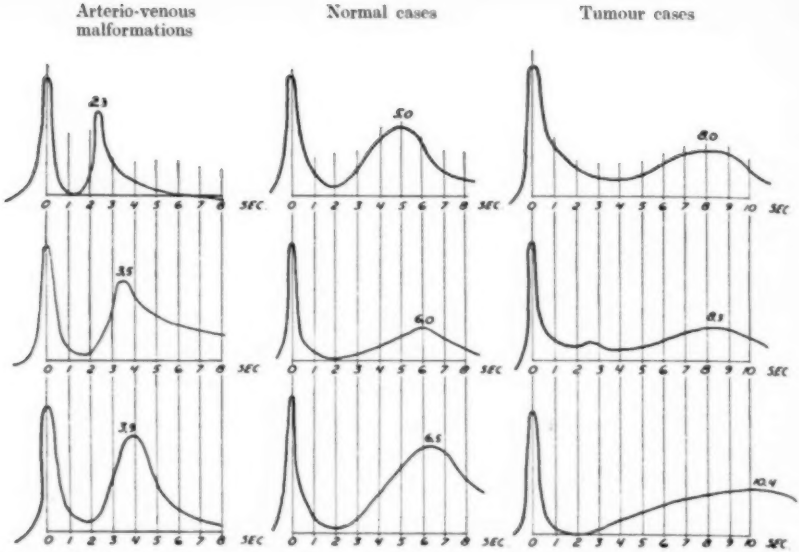

Diagram 6. Appearance of isotope curves in 'normal' cases differs from those obtained in cases of tumour or arterio-venous malformations.

the vascular malformation. By determining the transition between the filling and emptying phases in the drainage veins it is possible, by means of angiography, to compute the circulation time through the malformation. The circulation times through the malformations, determined by angiography, correspond, as is shown in Diagr. 5, with the circulation times resulting from the isotope experiments. On the other hand, there is no clear correlation with the circulation through the brain, which shows that the malformation causes an extensive shunt.

In cases of arteriovenous malformations the isotope curve has a characteristic appearance, rising steeply in the venous phase (Diagr. 6). When the circulation time is prolonged — for instance when a tumour is present — the venous curve is flat and its peak less well marked. This coincides with our experience from angiography.

In rapid serial angiography the circulation time was thus determined by measuring the time interval between maximum filling in the carotid siphon and in the parietal veins, since we have found these two points to be the best defined on the concentration curve. The values obtained, however, are not quite independent of the concentration and the amount of contrast medium or of the injection time. If contrast medium 25 % instead of 50 % is used, the observable filling of the veins ends much

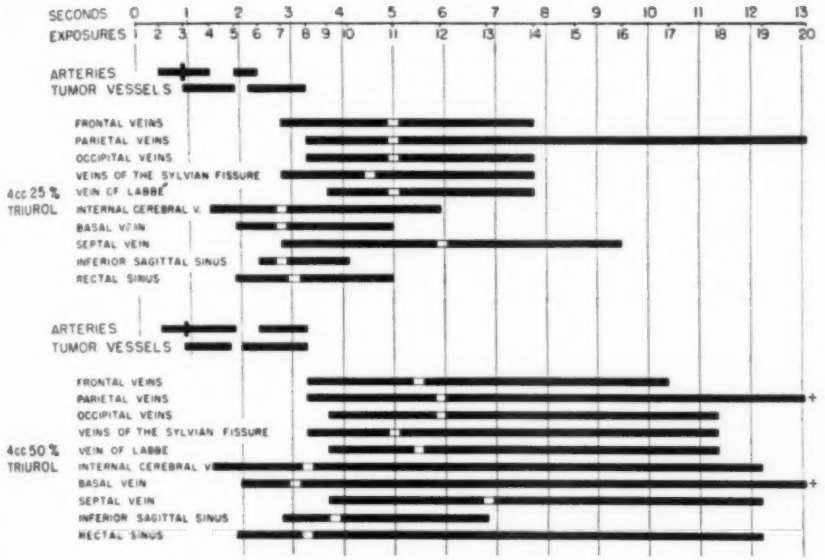

Diagram 7. Filling of the vessels of patient examined first with Triurol 50 % and then Triurol 25 %. In second examination venous phases considerably shorter and circulation time about 1 sec shorter, measured from point of maximum filling in carotid siphon to maximum filling of parietal veins. (Int. cerebral vein, basal vein, inf. sagittal sinus, and rectal sinus achieving maximum filling early is indication of tumour drainage.

sooner; the difference generally amounts to three to four seconds. The transition between the filling and emptying phases in the veins is also displaced so that the circulation time is shortened (Diagr. 6). In 9 double investigations, of which two were checked with isotopes, the circulation time was found to be 15 to 35 % shorter when contrast medium 25 % was used. At 37° C, the viscosity for Triurol 25 % is 1.274 centipoise, as compared with 2.094 centipoise for Triurol 50 %. The viscosity for contrast medium 25 % is thus so much lower that this probably accounts for at least the larger part of the differences. We have observed no alteration in the calibre of the vessels, following injection of contrast medium 25 % or 50 %.

The importance of the injection time has also been studied in 5 double examinations of 5 patients. Longer injection time always gave longer circulation time. The differences were small, however. In this material, the injection time has varied between 1 and 2.5 seconds. Variations of this magnitude have proved to be of practically no importance. Apart from the factors just mentioned as affecting the circulation time —

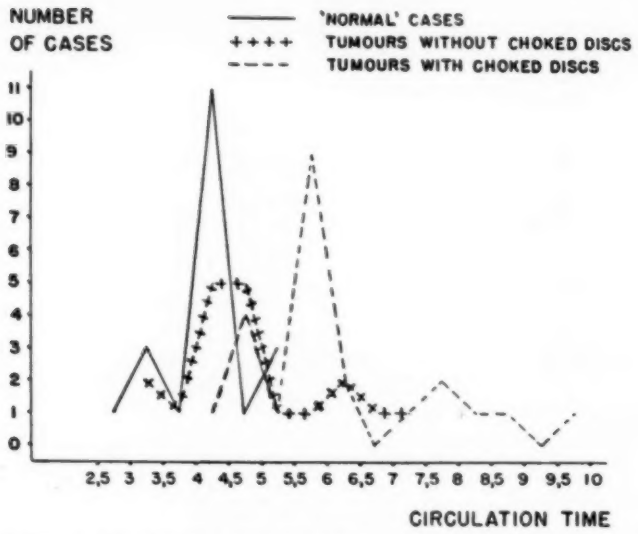

Diagram 8. Circulation times in 20 normal and in 42 tumour cases.

the amount and concentration of the contrast medium and the injection time — there are also variations in the patient. By repeated measurements of the circulation time, each patient being examined twice with the same technique, we have arrived at an approximate idea of how large the variations may be in one and the same patient. This material is yet too limited to permit any definite conclusions, but if we count with a variation of ± 20 %, including errors due to method, we are keeping within somewhat wider limits than the largest differences observed.

There are no cases in this material which may be said to be completely normal. The cases selected as normal have been those in which the main sign or symptom has been either epilepsy or headache, and they have been chosen among cases lacking any radiologically demonstrable vascular changes and without any manifest neurologic disturbances. This selected group consists of 20 cases, which, it is true, is a small material, but the values obtained are highly uniform (Diagr. 8). There was no difference between the patients with headache and those with epilepsy. Twelve — or more than half — of these had a circulation time with a minimum figure of 2.7 seconds. All, except one, were less than 30 years old. All the 4 patients, who had a circulation time of more than 4.5 seconds, were, on the other hand, more than 50 years of age. Although the material is too small to allow a definite conclusion, the results seem to indicate that older patients have a longer circulation time than younger ones. No children

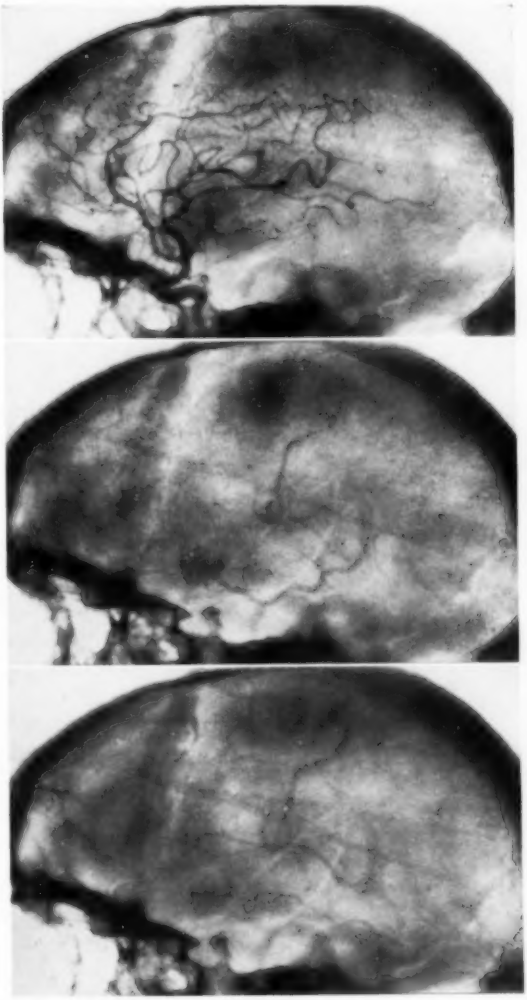

Fig. 2. Temporal deeply infiltrating astrocytoma without visible pathologic connections between arteries and veins. Two drainage veins from tumour; the basal vein and a superficial parietal vein well filled before all other veins; at later stage other veins are filled and it is not possible to decide which are drainage veins.

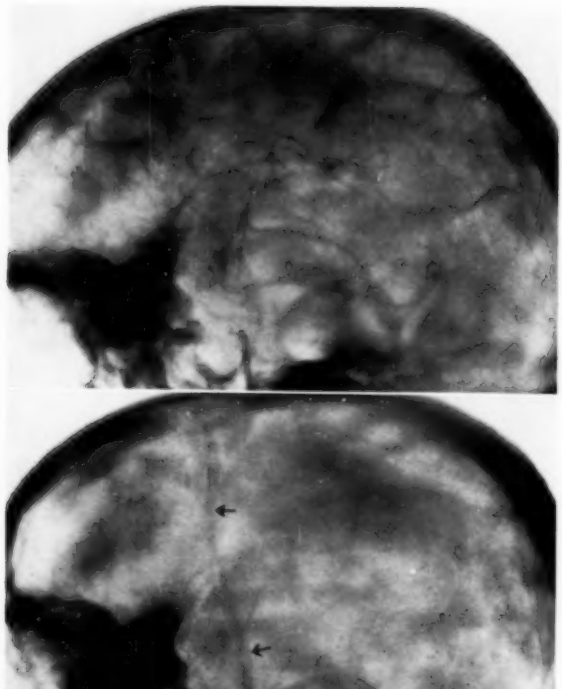

Fig. 3. Meningioma from pterion. Drainage vein, issuing from tumour area well filled with contrast medium after most other veins have emptied.

are included in this group, since they are examined under general anaesthesia.

Out of 42 patients with tumour, 23 had choked discs. These patients had an average circulation time of approximately 6 seconds, a marked increase over the epilepsy-headache group. The longest observed circulation time was 9.8 seconds. An even longer circulation time has been recorded in a case of thrombosis of the carotid artery with a collateral circulation through the orbit. Patients without choked discs appear to have a lower average circulation time that the preceding group, but higher than the normal group. No direct connection between the degree of choked disc and the circulation time has appeared from these investiga-

tions. Nor has any difference been found between the circulation times in cases of intracerebral and extracerebral tumours.

Brains with tumours have of course, like brains with arteriovenous malformations, two circuits, one through the normal brain tissue and the other through the lesion. In those cases where the drainage veins of the tumours can be identified, the point of maximal filling of these veins can be determined, and consequently also the circulation time through the tumour. Rapid serial angiography offers much greater possibility of analyzing the drainage conditions than routine examinations with a few films only. Among others, JOHANSSON has pointed out that in certain cases of tumours, which have no other direct signs of hypervascularization, dilated drainage veins may be observed. With rapid serial angiography, however, abnormal circulation time may be observed not only in such dilated veins but also in non-dilated veins, which may thus be identified as drainage veins. The emptying phase may begin either earlier or later than normal (Fig. 1 and Diagr. 2).

Fifteen out of the material of 42 tumour cases were vascular. In all these cases, with one exception, drainage veins could be identified. In 10 of the cases, there were pathologic connections between arteries and veins, observable during the arterial filling phase. With rapid serial angiography these connections can be demonstrated more easily and clearly.

Twenty-seven of the tumours were non-vascular. Out of these, 7 had demonstrable drainage veins which in 5 cases were not dilated. It would probably have been impossible to identify the drainage veins in these 5 cases without rapid serial angiography.

Out of the 42 tumour cases, drainage veins could thus be identified in a total of 21 cases, of which 14 had non-dilated drainage veins. In 5 cases, the circulation was slower through the tumour than through the rest of the brain. These cases were all meningeomas. In 16 cases, on the other hand, the circulation was more rapid through the tumour than through the remainder of the brain. In this group there were 12 gliomas, 2 metastases, and 2 cases of central, not verified tumour.

It thus appears that rapid serial angiography could become of great importance in determining tumour pathology. Rapid serial angiography also yields highly increased possibilities of clarifying the drainage conditions; a better idea of the tumour bed and more exact localization may therefore be obtained. With increasing experience in rapid serial angiography the advantages of this examination method are beginning to crystallize, and its value is becoming more apparent. It may not be long before an examination with cerebral angiography will be considered incomplete, if it is not a rapid cerebral angiography.

SUMMARY

The cerebral circulation time has been studied with rapid serial angiography and, for comparison, by means of radioactive isotopes. Techniques and errors of method are discussed. The circulation time determined by angiography seems to be best characterized as the time interval between concentration maxima in the carotid syphon and the parietal veins. Similarly, the circulation time in tumours and vascular malformations can be determined by registering the concentration maxima in drainage veins. The relationships between these circulation times — through brain and through lesion, respectively — seem of importance for the differential diagnosis.

ZUSAMMENFASSUNG

Die Zirkulationszeit in Hirngefässen ist mit Hilfe der schnellen Serienangiographie und vergleichsweise unter Benutzung radioaktiver Isotope studiert worden. Die Technik und die Fehlerquellen der Methoden werden besprochen. Die mit Hilfe der Angiographie bestimmte Zirkulationszeit scheint am besten als der Zeitinterwall zwischen dem Konzentrationsmaximum im Karotissyphon und in den parietalen Venen charakterisiert zu sein. In ähnlicher Weise kann die Zirkulationszeit in Tumoren und Gefässmissbildungen durch Registrierung der Konzentrationsmaxima in den Drainagevenen bestimmt werden. Die Beziehungen zwischen diesen Umlaufszeiten — durch das Gehirn bezw. durch das krankhaftveränderte Gebiet — scheinen für die Differentialdiagnose wichtig zu sein.

RÉSUMÉ

L'auteur a étudié les temps de circulation cérébrale par sério-angiographie rapide, et simultanément pour comparaison, avec des isotopes radioactifs. Il examine les techniques et les sources d'erreurs. La meilleure définition du temps de circulation déterminé par angiographie semble être de le considérer comme l'intervalle de temps entre les maximums de concentration dans le siphon carotidien et dans les veines pariétales. De même, le temps de circulation dans les tumeurs et dans les malformations vasculaires peut être déterminé par l'enregistrement des maximums de concentration dans les veines de drainage. Le rapport entre ces temps de circulation — à travers le cerveau et à travers la lésion — paraît important pour le diagnostic différentiel.

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AUS DEM MAX-PLANCK-INSTITUT FÜR HIRNFORSCHUNG, ABTEILUNG FÜR TUMORFORSCHUNG UND EXPERIMENTELLE PATHOLOGIE DES GEHIRNS, UND DER NEUROCHIRURGISCHEN UNIVERSITÄTSKLINIK (DIREKTOR: PROF. DR. W. TÖNNIS), KÖLN, DEUTSCHLAND

DER DIAGNOSTISCHE WERT EINER FUNKTIONELLEN SERIENANGIOGRAPHIE BEI INTRACRANIELLEN PROZESSEN

von

W. Schiefer

Die Beobachtung morphologischer Veränderungen, d. h. die Feststellung des Sitzes, der Ausdehnung und Gefässversorgung eines intracerebralen Prozesses hat bisher im Vordergrund angiographischer Untersuchungen gestanden. Durch Serienaufnahmen waren darüberhinaus auch zahlreiche Einzelbeobachtungen funktioneller Phänomene möglich (HEMMINGSON, KRAYENBÜHL, LIMA, LORENZ, MONIZ, SCHURR, WICKBOM u. a.). Da eine systematische Bearbeitung solcher Beobachtungen an einem grösseren einheitlich untersuchten Krankengut bisher fehlt, erschien es lohnend, diese kreislaufpathologischen Erkenntnisse einmal auf ihren differentialdiagnostischen Wert zu prüfen.

Unsere eigenen Untersuchungen wurden mit zwei verschiedenen Geräten vorgenommen:

Mit dem Serienangiographen nach TÖNNIS-BERGERHOFF (Koch u. Sterzel, Düsseldorf) konnten wir an variablen Kontrollzeitpunkten, die je nach Art des Prozesses verschieden gewählt wurden, den Durchfluss des Kontrastmittels registrieren und damit die Zirkulationszeit sowohl für den Tumor oder die Gefässmissbildung als auch für das Gesamthirn hinreichend sicher beurteilen. Bei dieser automatischen Apparatur werden unter und neben dem horizontalgelagerten Patienten zwei Spezialkassetten mit Hilfe eines Malteserkreuzes bewegt. In beiden Ebenen entstehen so gleichzeitig 4 Aufnahmen zu den jeweils gewünschten Aufnahmezeitpunkten.

Diese Aufnahmetechnik wurde ergänzt durch indirekte kinematographische Untersuchungen mit der Spiegel-Optik-Kamera (Odelca) von BOUWERS in Mittelformat. Die Rapidix-Kassette ermöglicht auf einem 3 m langen 70 mm breiten Filmband maximal 6 Aufnahmen pro Sekunde. (Diese Untersuchungen wurden gemeinsam mit RAUSCH durchgeführt.)

Die erwähnten Geräte wurden so kombiniert, dass Vergleichsuntersuchungen zwischen direkter Serienangiographie im Grossformat und der

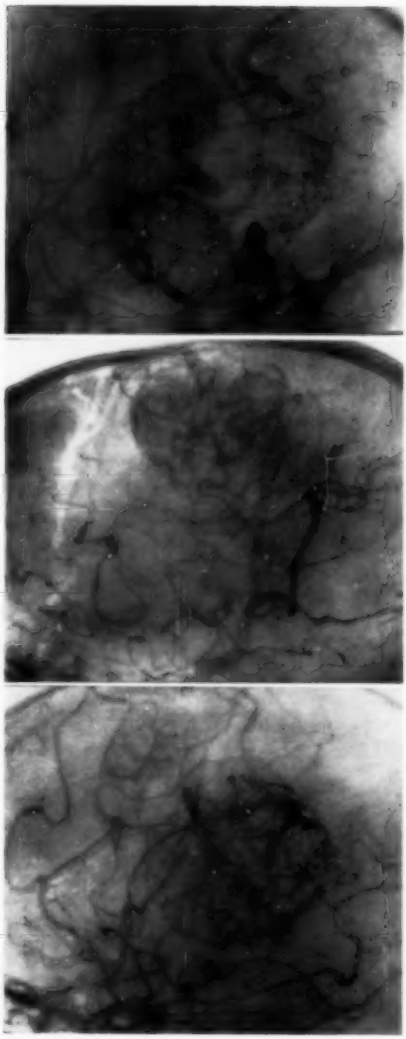

Abb. 1. Differentialdiagnostische Schwierigkeiten im Arteriogramm. *Oben:* Glioblastom; *Mitte:* Meningeom; *Unten:* Metastase.

indirekten Kinematographie beim gleichen Patienten leicht möglich waren. Bei beiden Apparaturen sind die Filmkosten verhältnismässig gering. Nur so war ihre routinemässige Anwendung im klinischen Betrieb und damit die grosse Zahl der Untersuchungen (innerhalb von 3 Jahren 2,500 Angiographien) möglich.

Von den verschiedenen kreislaufpathologischen Beobachtungen mit Hilfe der Serienangiographie möchte ich besonders eine Fragestellung herausgreifen, nämlich das Verhalten des Tumorkreislaufs zum übrigen Hirnkreislauf. Aus den gegenseitigen Beziehungen, d. h. der zeitlich unterschiedlichen Durchblutung des Tumors und der des Gesamthirns lassen sich nämlich wichtige differentialdiagnostische Hinweise für die Artdiagnose intracerebraler Prozesse gewinnen. Gelegentlich ermöglicht schon die Verschiedenartigkeit tumoreigener Gefässe im einfachen Arteriogramm Rückschlüsse auf die histologische Struktur eines Tumors. Andererseits ergeben sich aber häufig erhebliche Schwierigkeiten für die präoperative Artdiagnose. Als Beispiel seien hier die Gefässbilder eines Glioblastoms, eines Meningeoms und einer Metastase angeführt (Abb. 1). Mit hinreichender Sicherheit lässt hier das einfache arteriographische Zufallsbild weder eine Art- noch Malignitätseinteilung zu. Das gleiche kann auch für Fälle mit einer homogenen Tumoranfärbung gelten. Auch hier ist ohne Serienbild eine Differentialdiagnose nicht mit Sicherheit möglich.

Aus dem angegebenen Schema (Diagramm 1) lassen sich nun die Beziehungen zwischen der Darstellung eines Tumors und den verschiedenen Phasen der übrigen Hirnzirkulation entnehmen. Oben ist die Kreislaufzeit für einen Normalfall schematisch angegeben.

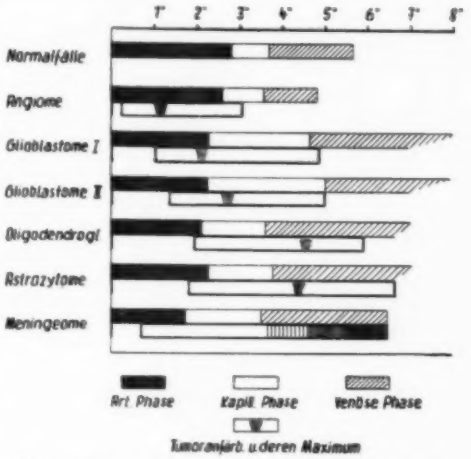

Diagramm 1. Schema über die Beziehungen zwischen Tumor- und Gesamthirnzirkulation bei den einzelnen Geschwulstarten.

Einen Modellfall für das unterschiedliche Verhalten von Tumorzirkulation und Hirnzirkulation stellen die arteriovenösen *Angiome* dar. Sie sind Missbildungen, in denen durch die sehr zahlreichen arteriovenösen Fisteln der periphere Kreislaufwiderstand herabgesetzt wird. Die Zirkulationszeit des Angioms wird dadurch verkürzt, während die Kreislaufzeit des Gesamthirns gewöhnlich normal bleibt.

Tab. 1

Kreislaufzeiten und Werte der Hirndurchblutungsmessung nach Kety bei 13 arteriovenösen Angiomen

Nr.	Sitz des Angioms	Angiomgrösse[1]	Kreislaufzeit (sec)		Hirndurchblutung (cm^3 100 g/min)		Bemerkungen
			Hirn	Angiom	vor Eingriff	nach Eingriff	
1	parietal li.	29.5	3.6	3.7	239.0	—	—
2	diffus Grosshirn re.	—	—	—	230.0	240.0	Nach A. car. comm.-Ligatur bds.
3	frontomedial re...	17.8	3.5	2.8	163.0	—	—
4	zentral re.	18.5	4.6	3.5	145.0	—	—
5	parietal re.	13.4	3.9	3.1	136.0	58.0	Nach Exstirpation des Angioms.
6	frontoparietal li. .	5.0	5.5	2.8	105.0	61.6	Nach Exstirpation des Angioms.
7	parietal li.	11.7	4.6	2.8	96.0	54.1	Nach Exstirpation des Angioms.
8	occipital li.	5.9	4.6	2.8	90.0	100.0	Nach A. car. ext. Ligatur bds.
9	occipital re.	4.9	5.6	2.9	88.1	62.0	Nach Exstirpation des Angioms.
10	Seitenventrikel re.	3.3	5.6	2.9	84.0	48.2	Nach Exstirpation des Angioms.
11	occipital li.	15.0	4.6	2.8	72.8	70.1	Nach A. occipit.-Ligatur li.
12	temporofrontal...	4.0	6.3	—	57.1	—	Angiom der A. car. ext.
13	frontomedial li. ..	6.1	7.4	3.7	42.9	66.5	Nach Exstirpation des Angioms und Ausräumung einer frischen Blutung im li. Frontallappen.

[1] Planimetrisch bestimmt.

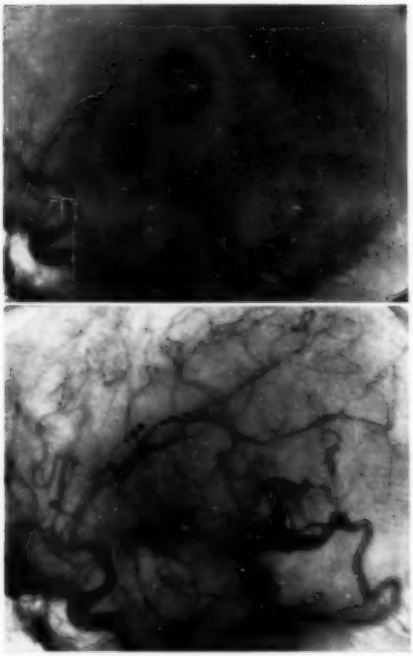

Abb. 2. Serienangiogramm eines 42-jährigen Mannes mit einem Glioblastom rechts temporal. Man erkennt die vorzeitige Darstellung der zu- und abführenden Gefässe. Beschleunigte Tumorzirkulation. Grosse arterio-venöse Fisteln.

Der Zirkulationsbeschleunigung im Angiogramm entsprechend lässt sich bei der Hirndurchblutungsmessung nach KETY und SCHMIDT bei den meisten Angiomen eine Steigerung der Hirndurchblutung auf das 3 bis 4-fache der Norm feststellen. Die Tabelle 1 zeigt die Werte bei 13 gemeinsam mit GÄNSHIRT untersuchten arteriovenösen Angiomen. Die Zirkulationszeit durch die Angiome ist verkürzt. Wenn wir die normale Durchblutung des Hirns mit 54 ccm/100 g Hirngewebe und Minute annehmen, so liegt die Durchblutung nur in dem letzten Falle unter der Norm. Auch hier bleibt die Kreislaufzeit durch das Angiom verkürzt, die Kreislaufzeit des übrigen Hirns ist aber im Vergleich zu den anderen Fällen verlängert. Die Klärung dieses eigentümlichen Verhaltens brachte hier das Angiogramm, das neben dem arteriovenösen Angiom eine Volumenszunahme des linken Stirnhirns infolge einer intracerebralen Blutung aus dem Angiom erkennen liess. Die intracranielle Druckerhöhung hatte hier zu einer Minderung der Durchblutung bei der Fremdgasanalyse nach KETY und zu einer Verlangsamung der Hirnzirkulation im Angiogramm geführt. Die Kreislaufzeit des Angioms selbst blieb davon unberührt.

Eine ähnliche kreislaufpathologische Situation treffen wir nun auch beim *Glioblastoma multiforme* an. Auch hier findet sich ein Shunt, d. h. die Gefässstrecke zwischen zuführenden Arterien und abführenden Venen ist kurz. Entsprechend wird angiographisch eine sehr frühzeitige und kurzdauernde Tumordarstellung zu erwarten sein. TÖNNIS hat 1936 auf den »Angiomcharakter« dieser Tumorart hingewiesen, wobei er sich auf die Operationsbeobachtung von arteriellem Blut in den Venen der Tumorumgebung stützen konnte.

Wir haben bei den Glioblastomfällen nach angiographischen Gesichtspunkten 3 Gruppen unterschieden:

a) Beim angiomatösen Typ des Glioblastoms sind die kreislaufpathologischen Verhältnisse denen des arteriovenösen Angioms ausserordentlich ähnlich. Auch hier findet sich eine vorzeitige Darstellung und Hypertrophie der zuführenden Arterienzweige. Ausserdem wiederum eine vorzeitige Venendarstellung als Ausdruck der beschleunigten Zirkulation im Tumor (vergl. Abb. 2).

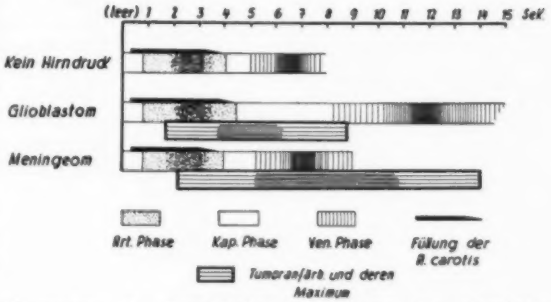

Diagramm 2. Graphische Darstellung der einzelnen Phasen der Hirnzirkulation. Beziehungen zwischen Tumor- und Gesamthirnzirkulation beim Glioblastom und Meningeom (Untersuchungen mit der Odelca-Kamera).

b) Eine weitere Gruppe des Glioblastoms, die nur eine Darstellung des Tumors, nicht aber den angiomatösen Aufbau erkennen lässt, zeigt neben der Kontrastdarstellung immer auch vorzeitige Venendarstellungen, d. h. die raschere Durchblutung des Tumors. Diese Tatsache wird sich später bei den Oligodendrogliomen und Astrocytomen als differentialdiagnostisch entscheidendes Merkmal herausstellen.

c) Bei einer letzten Gruppe der Glioblastome wird jegliche Tumordarstellung vermisst. Wie wir früher gemeinsam mit UDVARHELYI und WALTER beschrieben haben, stehen bei der histologischen Untersuchung solcher Fälle fast immer stark proliferativ veränderte und thrombosierte Gefässe im Vordergrund.

Alle 3 genannten Gruppen der Glioblastome haben darüberhinaus noch ein gemeinsames Kennzeichen, nämlich eine meist hochgradige Verlangsamung der Gesamthirnzirkulation (bis zu 16 und 18 Sek., vergl. Diagramm 2). Bis zu einem gewissen Grade kann diese Tatsache auch für die Fälle der dritten Gruppe, welche sonst keine Anfärbung zeigt, differentialdiagnostisch ausgenutzt werden. Eine derartig auffällige Zirkulationsverlangsamung wird bei allen übrigen Tumorarten vermisst.

Bei *Astrocytomen* und *Oligodendrogliomen* ist nur in etwa einem Drittel der Fälle eine Tumordarstellung zu beobachten. Im Gegensatz zu den Glioblastomen erscheint hier die Tumoranfärbung jedoch frühestens in der kapillaren Phase. Das Maximum der Darstellung findet sich erst während des Venenbildes. Wir vermissen weiter die vorzeitige Venendarstellung im Tumorbereich und eine stärker verzögerte Gesamthirnzirkulation wie beim Glioblastom. Trotzdem muss die Feststellung einer Tumoranfärbung beim Astrocytom und besonders beim Oligodendrogliom den Verdacht auf eine maligne Entartung oder zumindest erhebliche Polymorphie aufkommen lassen.

Ein 16-jähriges Mädchen klagte seit 9 Jahren über cerebrale Anfälle. Die Veränderungen am Knochen wiesen auf einen schon länger bestehenden gutartigen Prozess hin. Das Angiogramm zeigte alle Veränderungen eines malignen Tumors. Den Widerspruch klärt das histologische Bild. Es handelte sich um ein sehr polymorphes Oligodendrogliom mit zahlreichen Mitosen. Unter Berücksichtigung der Vorgeschichte, des angiographischen und histologischen Befundes wird es sich demnach um ein primär gutartiges Oligodendrogliom gehandelt haben, das später maligne entartete.

In 3 Fällen konnten wir solche Anfärbungen auch bei Tumoren beobachten, die 1 bis 2 Jahre nach der Operation mit einem Recidiv eingewiesen wurden. Vor der Operation hatten sich keine pathologischen Gefässe im Tumorbereich nachweisen lassen.

Die *Meningeome* zeigen nun ein völlig abweichendes Verhalten von allen bisher geschilderten Beobachtungen. Es handelt sich hier um eine Tumorgruppe mit einem kapillären Gefässcharakter. Infolge der grossen Zahl der Gefässe ist hier zwar auch der periphere Widerstand erniedrigt. Die Gefässstrecke ist aber insgesamt stark verlängert. Nur so ist zu verstehen, dass die Darstellung des Tumors schon früh in der arteriellen Phase beginnt, aber dann auch sehr lange anhält. Meist erscheint als erstes ein kapillares Netz, das von Phase zu Phase an Intensität zunimmt und dessen Darstellung immer homogener wird. Bei Beobachtung dieser funktionellen Besonderheiten sind auch sogenannte angioblastische Meningeome, deren Differentialdiagnose gegenüber dem Glioblastom, dem Sarkom und der Metastase im einfachen Arteriogramm oft Schwierigkeiten bereitet, im Serienbild leicht zu erkennen wie der folgende Fall beleuchtet.

Ein 52-jähriger Mann mit einem Tentoriummeningeom. Vor 4 Jahren wurde aufgrund eines einzelnen arteriographischen Bildes die Diagnose maligner Tumor gestellt (Abb. 3 oben links). Erst die weiteren Bilder lassen in der Serie die typische homogene Anfärbung des Meningeoms erkennen (Abb. 3).

Bei cerebralen *Metastasen* lässt sich serienangiographisch in etwa 40 Prozent eine spezifische Tumorzirkulation nachweisen. Diese hat zum Teil Ähnlichkeit mit der des Meningeoms, zum Teil mit der des Glioblastoms. Die evtl. Multiplizität des Prozesses, seine Abgrenzung und Grösse lässt aber eine Trennung von den genannten Tumorarten zu. Der Zeitpunkt der Tumordarstellung innerhalb der Gesamthirnzirkulation liegt hier je nach ihrer Form in der kapillaren bis venösen Phase des Gesamthirns.

Mit der Odelca-Kamera lassen sich die eben genannten kreislaufpathologischen Besonderheiten der einzelnen Hirntumorarten noch eingehender untersuchen. Auf dem Diagramme 2 wurden die genauen zeitlichen Verhältnisse zwischen den einzelnen Kreislaufphasen des Hirns und des Tumors eingetragen. Man erkennt die teilweise erhebliche Zirkulationsverlangsamung bei den Tumoren etwa im Vergleich zum arterio-

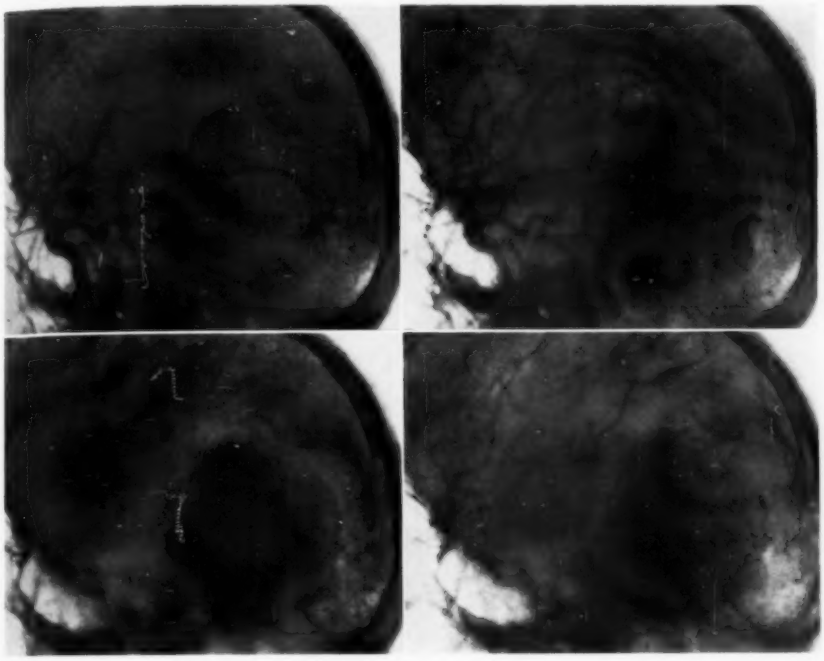

Abb. 3. Serienangiogramm eines 52-jährigen Mannes mit einem Tentoriummeningeom.

venösen Angiom. Wie sich feststellen lässt, kommt diese Zirkulationsverlangsamung nicht so sehr in der arteriellen sondern durch eine auffällige Verlängerung der kapillaren Phase (bis zu 4.0 Sek.) zustande. Auch die venöse Phase ist bei gesteigertem Schädelinnendruck verlängert, sodass sich zum Beispiel im zweiten Fall eine Gesamtzirkulation von über 15 Sekunden ergibt.

Aus den Odelca-Serien sollen abschliessend noch einige Angiogramme gezeigt werden. Beim Glioblastoma multiforme hat die Dissoziation zwischen beschleunigter Tumorzirkulation und verlängerter Gesamthirnzirkulation häufig zu der Annahme geführt, dass auch bei dieser Tumorart eine Anfärbung über die Zeit der Gesamthirnzirkulation hinaus bestehe. Auf Angiogrammen kommt während der verlängerten kapillaren Phase der Tumor oft fast allein zur Darstellung. Wie sich mit der Odelca-Kamera eindeutig zeigen lässt, folgt dann erst nach Beendigung der Tumorzirkulation die oft erheblich verlängerte venöse Phase. Beim Meningeom sieht man ein völlig davon abweichendes Verhalten (Abb. 4). Die Gesamthirnzirkulation ist mit 9 Sekunden beendet. Die Tumoranfärbung hält dagegen über 13 Sekunden lang an.

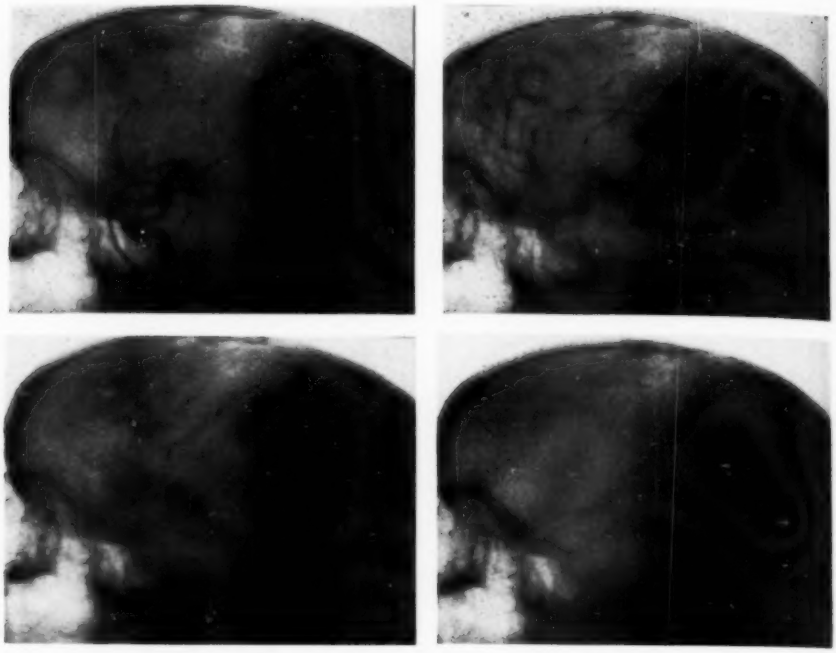

Abb. 4. Konvexitätsmeningeom re. parietal. *Oben links:* Externagefässe ziehen zum Tumornabel. *Oben rechts:* Kapillares Netzwerk in der arteriellen Phase; *Unten:* zunehmend homogene Tumoranfärbung, die länger als die übrige Hirnzirkulation anhält (Abbildungen aus einer Odelca-Serie, vergl. auch Diagramm 2).

Die Tabelle 2 zeigt die Möglichkeiten, die sich anhand serienangiographischer Untersuchungen bei Beachtung funktioneller Besonderheiten für die Differentialdiagnose der Grosshirngeschwülste ergeben. Ein Vergleich unserer früheren Ergebnisse mit der einfachen Arteriographie lässt deutlich den grossen Fortschritt einer messbaren Serienangiographie erkennen.

Wir haben aus den vielen diagnostischen Möglichkeiten, welche uns die Serienangiographie bietet, nur das Verhältnis des Tumorkreislaufs zum Hirnkreislauf herausgegriffen. Auf die Bedeutung des Phlebogramms für die Lokaldiagnose durch Verlagerung der tiefen Venen oder Ausfall der oberflächlichen Venen, auf kreislaufphysiologische Beobachtungen bei Mangeldurchblutung bestimmter Hirnabschnitte, auf Gefässverschlüsse, Sinusthrombosen und einer Reihe anderer Krankheitsbilder, deren Diagnose nur serienangiographisch gesichert werden kann, möchte ich nicht eingehen.

Tab. 2

Artdiagnose der Grosshirngeschwülste durch Angiographie (Vergleich zwischen einfacher Arteriographie und Serienangiographie)

	Einfache Arteriographie		Serienangiograph. Artdiagnose möglich
	uncharakteristische Tumoranfärbung	Artdiagnose möglich	
Glioblastome	11 %	46.5 %	76 %
Astrozytome	18 %	—	29.5 %
Oligodendrogl.	10 %	—	34.5 %
Meningeome	31 %	11 %	38 %
Metastasen	12 %	—	40 %

Die Bedeutung der kollateralen Blutversorgung geht aus dem folgenden Falle hervor.

Ein 16-jähriges Mädchen mit einem grossen Aneurysma der linken Art. cerebri media hatte einen regelrechten neurologischen Befund, keine Sprachstörungen, keine Paresen. Das Aneurysma konnte nach Stielligatur total exstirpiert werden. Bei der postoperativen Kontrolle ergab sich ebenso wie vor der Operation keine Darstellung der mittleren Gehirnarterie, obwohl auch jetzt keine Paresen zu beobachten waren. Der Grund liess sich aus dem angiographischen Bild ablesen. In der kapillaren Phase der Hirnzirkulation kamen nämlich nun die rückläufig aus dem Gebiet der Art. cer. ant. und Art. cer. post. gefüllten Arterien zur Darstellung und boten damit die Erklärung für den trotz des Gefässverschlusses normalen klinischen Befund.

So ergeben sich durch serienangiographische Untersuchungen viele neue Erkenntnisse. Je mehr neben den bisher bekannten morphologischen Veränderungen auch kreislaufphysiologische Gesichtspunkte Berücksichtigung finden, umso grösser wird der Gewinn für die präoperative Diagnose intracerebraler Prozesse sein.

ZUSAMMENFASSUNG

Die Bedeutung der cerebralen Angiographie erschöpft sich nicht im Aufzeichnen morphologischer Veränderungen, also Beobachtung von Verlagerungen der Arterien und Venen sowie Veränderungen an den Tumorgefässen selbst. Anhand von nunmehr 2,500 Untersuchungen mit direkter Serienangiographie (TÖNNIS-BERGERHOFF) und indirekter Kinematographie (Odelca-Spiegel-Optik-Kamera) war darüber hinaus eine Klärung der funktionellen Besonderheiten der einzelnen intracerebralen Prozesse möglich. Insbesondere liessen hierbei die gegenseitigen Beziehungen von Tumor- und Hirnkreislauf wesentliche Rückschlüsse auf die Artdiagnose der Hirngeschwülste zu.

SUMMARY

The importance of cerebral angiography is not limited to observations of morphologic changes, *i. e.* demonstration of displacements of arteries and veins and changes in the tumour vessels proper. In a material of 2,500 cases, examined with direct serial angiography (TÖNNIS-BERGERHOFF) as well as indirect cinematography (Odelca-Spiegel-Optik-Camera), it was possible to clarify the special functions of individual intracerebral processes and to reach essential conclusions, in particular for the differential diagnosis, from the mutual relationships between the tumour and cerebral circulations.

RÉSUMÉ

L'intérêt de l'angiographie cérébrale ne se borne pas à la mise en évidence de modifications morphologiques, telles que les déplacements d'artères et de veines et les modifications des vaisseaux tumoraux eux-mêmes. Sur 2,500 examens par sério-angiographie directe (TÖNNIS-BERGERHOFF) et cinématographie indirecte (caméra à miroir Odelca) il a été en outre possible de dégager les caractéristiques fonctionnelles des diverses lésions intracérébrales. En particulier, les relations réciproques entre les circulations tumorale et cérébrale ont permis des conclusions essentielles pour le diagnostic de nature des tumeurs cérébrales.

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CEREBRAL CINE-ANGIOGRAPHY WITH THE IMAGE INTENSIFIER

by

H. Verbiest and *J. Feddema*

In an increasing number of publications the advantage of making more than three exposures in cerebral angiography, as in the current technique, is stressed. More exposures will afford the possibility of investigating variations and characteristic features in a normal or pathologic circulation; the absence of filling of a cerebral vessel may enable a diagnosis of vascular occlusion to be made with more certainty, and there will be more chance of the essential patterns of an abnormal circulation being visualized in the films.

The newer methods may be divided into two groups. To one group belong the techniques of obtaining rapid serial roentgen films, either of normal size by means of direct roentgenography or of smaller sizes by indirect photography, for instance with a mirror camera. To the other group belong the methods of cineroentgenography. The reports concerning the latter method are devoted to cine-fluorography, the so-called indirect method.

During recent years considerable advances in cine-fluorography have been obtained by the introduction of the principles of television and of controlled electron acceleration. The main advantage of these new methods above the older ones is that the total roentgen dose on the patient can be considerably reduced.

We reported our first efforts with cine-fluorography during cerebral angiography in human subjects by means of a Philips roentgen image intensifier at the Fifth International Congress of Neurology in 1953. A cinematographic record of the carotid circulation obtained with a total dose of 1.5 r, was shown. As the useful screen diameter of the tube amounted to 125 mm, only part of the angiogram could be examined. Further research in the Philips laboratories resulted in the construction

of a larger experimental image intensifying tube with a useful screen diameter of 270 mm. A further difference from the method reported in our previous paper was the employment of a mirror camera.

Description of the Experimental Stand

The roentgen image intensifying tube. The construction of the intensifying tube was based on the same principles as were applied in the tube previously used. The more important details of the unit are illustrated in Fig. 1. A fluoroscopic screen (2) is mounted in an evacuated glass bulb (1). Roentgen rays are transformed by this screen into visible light, as in normal fluoroscopy. The light of the image frees electrons from the sensitive photocathode (3) which is in close contact with the fluorescent screen at that point and to the roentgen intensity. In this way, the fluoroscopic image with all its variations in intensity is converted into an electronic image with corresponding variations in electronic density.

By applying a voltage of, say, 25 kV between the photocathode and the open anode (4), which latter is placed at the opposite extremity of the glass bulb, the electrons emitted by the photocathode are accelerated and focussed on a viewing screen (5) where the energy of the impinging electrons is converted into visible light. This image is much smaller than that of the fluorescent screen. The brightness of this image, however, is considerably greater. This increased brightness is obtained:

1) because the electrons have been accelerated by the applied high voltage; the higher the velocity of an electron when impinging on the viewing screen, the more visible light will it yield; with a voltage of 25 kV, a factor of 10 is obtained;

2) by the gain resulting from the electron-optical reduction of the size of the image; in this tube the reduction factor amounts to 5, which means a 25 times greater brightness of image.

The image formed on the viewing screen may be photographed by means of a cinecamera.

The mirror cinecamera. In comparison with the equipment used for experiments reported in our previous paper, a more favourable condition exists with the present method to use a mirror optical system, especially as regards the reduction factor between image (5) and film image (8).

The advantages of mirror systems over lens systems are.

1) They are free from chromatic aberrations.

2) They have a large light-gathering power; spherical aberrations inherent to the use of mirrors may be eliminated by the use of a Schmidt correction plate.

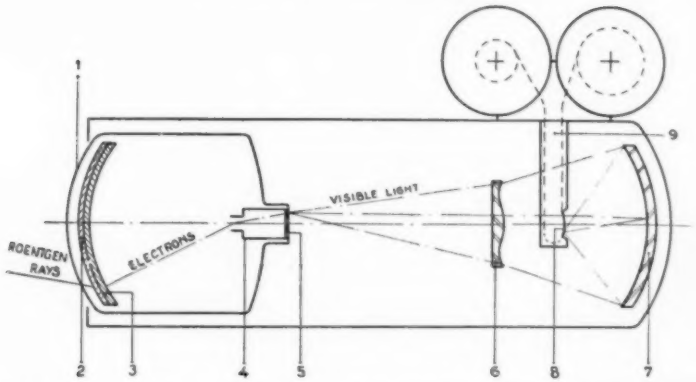

Fig. 1. Schematic drawing of unit consisting of intensifying tube and cinecamera.

The system used is illustrated in Fig. 1. The light from the image on the viewing screen (5) passes through the correction plate (6) and a smaller image is formed by the mirror (7) on the film (8) which is moulded to the required spherical shape and moved by a transport mechanism (9). The image on the viewing screen may be observed by an optical system (not shown in the schematic drawing). This system is of importance because it enables the investigator to control the exact positioning of the object, and to follow the course of the procedure.

Film choice. Preference is given to perforated 35 mm film as used in the cinematograph industry. This is done on the following combination of grounds.

1) Standard equipment may be used (projectors, darkroom apparatus, etc.).

2) With smaller film sizes the quality of the picture will suffer by the relatively greater influence of the grain of the emulsion, and should the grain size be reduced in proportion to the film size, sensitivity will be diminished and a larger amount of radiation will be required to obtain satisfactory film blackening.

3) With larger film sizes, more information might be obtained but the intermittent movement of the film then becomes impracticable.

Roentgenographic details. With a six-valve apparatus, 0.3 mm focus tube, and 1 mm Al filter, the best exposure data were obtained at 72 kV. Eighteen mA were necessary to obtain correct blackening of Gevaert Ortho Scopic G film at an exposure rate of 16 images per second. Without overloading the roentgen tube, a continuous exposure time of 20 to 25 seconds was possible. The total dose of radiation in this case during 25 seconds of filming amounted to 6.5 r, and with the previous screening

Fig 2. Image obtained with the unit described.

which was necessary for the exact positioning of the object, an additional 3 r may have been reached.

Before filming, the correct intensity of radiation was determined by means of a small luminosity meter directed towards the viewing screen of the image intensifying tube. A small plastic prism was employed to diminish the roentgen beam in marginal areas of the skull, which might otherwise have been overexposed (Fig. 2).

Owing to the horizontal position of the patient with slight retroflexion of the head, the moving image is reversed. This inconvenience cannot be eliminated at present because the experimental stand cannot be rotated around its optical axis. The problem is still under consideration.

SUMMARY

The authors describe an experimental image intensifying tube with a useful screen diameter of 270 mm, as compared with the screen diameter of 125 mm of the tube which formed the subject of their previous communication. The essentials of the technique of cerebral cine-angiography are generally discussed, with special reference to the important advantages obtaining by the employment of the new tube.

ZUSAMMENFASSUNG

Die Verfasser beschreiben eine experimentelle Bildverstärkerröhre mit einem gut anwendbaren Schirmdurchmesser von 270 mm und vergleichen sie mit dem Schirmdurchmesser von 125 mm einer von ihnen früher beschriebenen Röhre. Das Wesentliche der cerebralen Kineangiographietechnik wird in grossen Zügen besprochen; dabei werden die bedeutenden Vorteile, welche die Benutzung der neuen Röhre bietet, besonders berücksichtigt.

RÉSUMÉ

Les auteurs décrivent un tube intensificateur d'image expérimental dont l'écran a un diamètre utile de 270 mm, et le comparent au diamètre de 125 mm de l'écran du tube qui était l'objet de leur précédente communication. Ils étudient d'une façon générale les points essentiels de la technique de la ciné-angiographie cérébrale et insistent spécialement sur les importants avantages fournis par l'emploi de ce nouveau tube.

FROM THE ROENTGEN INSTITUTE (DIRECTOR: PROF. DR. H. VIETEN) OF THE SURGICAL CLINIC (SUPERINTENDENT: PROF. DR. E. DERRA) OF THE MEDICAL ACADEMY OF DÜSSELDORF, GERMANY

CEREBRAL SERIAL ANGIOGRAPHY ON 70 MM FILM SIZE

by

Heinz Vieten

Functional diagnostic surveys, *e. g.* of cerebral haemorrhage, or angiographic diagnosis of the nature of cerebral tumours, necessitate the taking of numerous films in rapid succession. This, as is well known, can be achieved by different methods:

1) direct contact serial roentgenograms of large size;
2) indirect serial roentgenograms of reduced size:
   a. fluorescent screen photographs (called 'fluorographs') with a purely optical image
      α) small size (on film 35 mm wide);
      β) medium size (on film 70 mm wide);
   b. photographs of an electronically amplified screen image, using image amplifier valves.

On the strength of our experience with the Odelca fluorographic camera in angiocardiography (6), the medium-size fluorograph seemed to be also suitable for cerebral angiocardiography. The main point in its favour was the substantially lower material cost as compared with the large size. This fact is important, although the value of a clinical method of survey and its practical application should not in principle be decided by the cost involved; however, the chances are that the large-size film method, and hence the scope of functional diagnostics, would in any case be restricted by this factor if no cheaper methods were available. An additional advantage of the medium size is that several pictures in succession can be viewed at a time and compared with each other without difficulty, thus permitting a very good survey and facilitating the evaluation of a series completed.

Compared with small-film fluorography, the medium-size film is not only superior in picture quality but offers the further advantage of being directly observable (maybe with the aid of a magnifying glass), there being no need for each picture to be photographically enlarged or projected on a screen.

However, along with the advantages which we have outlined in the foregoing, fluorography presented certain difficulties in regard to fine detail, loading of the roentgen tubes, protection against radiation, etc.

Our very first tests showed that in the usual, familiar type of Odelca camera with a 40 × 40 cm fluorescent screen, a film size of 63 × 63 mm and hence a reduction of 1 : 6.4, the detail is generally insufficient for the production of cerebral angiograms that will permit of satisfactory interpretation (4). BOUWERS (2) therefore designed on our behalf a special Skull-Odelca with a fluorescent screen of only 24 × 24 cm. This means that the scale of reduction for the same picture size (63 × 63 mm) is only about 1 : 4, with the result that there is practically no other determining or limiting factor to the detail than the quality of the fluorescent screen.

The fact is that, with a reduction of 1 : 4, or less, the unsharpness caused by the comparatively coarse grain of the highly sensitive fluorographic film falls below the limit of observability. Good mirror objectives — at small focal lengths this applies particularly to BOUWERS' concentric mirror system (1) — do not give rise to a subjectively discernible unsharpness even when working with very high luminosities (G. R. A. for the Skull-Odelca = 1 : 0.7; for the large Odelca = 1 : 0.75. The designation "G. R. A." — general relative aperture — used here merely serves for comparing the various types of Odelca). Geometrical unsharpness with the usual size of focus of not more than 1.2 × 1.2 mm, and for a focus—screen distance of at least 80 cm, is also negligible.

For the sake of comparison surveys have been carried out with different types of phantoms (Siemens Star, Schober Phantom, wire grid, grid with lines). With these grids the resolving power of the Skull-Odelca lies between 1.5 and 3 lines per mm, being naturally subject to variation within these limits as a function of the contrast. This is shown by the fact that the lead bars of stationary grids having 21 bars, and of a grid placed at our disposal having 28 bars per cm are discernibly reproduced, though with less contrast than in large-size roentgenograms. For cerebral angiography this means that vessels with a diameter of roughly 0.5 mm are reproduced, when filled with sufficient contrast fluid.

The improvement of the resolving power as compared with the 'large' Odelca, which has a reduction factor of 1 : 6.4, is not very substantial for the interpretation of films of phantoms with test lenses. The objective

gain is less than one third (about 0.5 line per mm). For the clinical interpretation of films this increase in distinction of detail is nevertheless considerable, because along with the objective improvement the lower reduction factor naturally makes the subjective evaluation of detail very much easier from physiological and optical points of view.

A far greater problem is presented by the fact that, compared with direct large-size roentgenograms the taking of fluorographs, even with mirror objectives of high luminosity, necessitates the employment of a 3 to 5 times larger amount of radiation, depending upon screen brightness and film sensitivity. This entails several consequences. As a result of increasing the amount of radiation for each individual picture it is also necessary to lengthen the exposure time in a similar ratio, as it is not possible to provide sufficient compensation by shortening the exposure or distance, or by increasing the voltage; this would give rise to other drawbacks which are unacceptable (geometrical unsharpness, loss of contrast, etc.). The longer exposure, however, will in any case result in greater motion blur. In consequence of this, the diagnostic possibilities of fluorography on medium-sized film in the case of very rapid motions are undoubtedly restricted. For cerebral angiography, however, this fact is of very little consequence. The movements of the brain vessels, unlike those of the heart and the cardiac valves, are of an order of magnitude that barely permits of reproduction in roentgenograms. These movements do not, therefore, cause any motion blur likely to detract from the detail.

More detrimental are the larger amounts of radiation (and hence longer exposure times) required for this class of work, resulting in higher loading of the roentgen tubes.

The tube load is given by the (adjustable) tube performance (in watts or kW) times the sum of the exposure times (sec) of all the pictures in a series. At the picture frequencies used (about 1 to 6 pict./sec) there is hardly any rest period to permit heat dissipation from the anode. The loading capacity of roentgen tubes with a sufficiently small focus — we operate with a Müller Rö 30 and 6-valve apparatus DA 1,000 — is limited in terms of watt-seconds, which means that we have to arrive at a compromise between tube performance and switch-on period, which latter must be uniformly distributed over the individual exposures. As, at the given tube performance (about 2/3 of the maximum permissible performance as shown by the nomogram), each roentgenogram takes a certain time, the total number of roentgenograms of a series depends upon the exposure time of the individual pictures.

With the Skull-Odelca as used by us up to the present it is possible to take a continuous series of 16 to 20 lateral skull roentgenograms (depending upon the size of head of the patient) having the necessary film density for angiography. Details as to exposure data, etc., have been published elsewhere (7). It is therefore possible, *e. g.* with a picture frequency of 2 pict./sec, to cover a total time of 8 to 10 sec or, with

5 pict./sec, a time of 3 to 4 sec. This is usually sufficient for serial angiograms of the brain. If not, the pre-set time may be extended by means of the 'Program Selector' with automatic change of frequency (5).

In this way the problem of taking serial cerebral angiograms by means of fluorography on medium-size film may be considered as technically solved. However, we found it necessary to point out (7) that the use of the Skull-Odelca with the present luminosity exhausts practically all reserves, so that in this way the possible limits have been reached. This is particularly evident in the case of serial films in the sagittal direction. For these, the total number of pictures must be reduced to a maximum of 8 to 10 in a series, and even then voltages of 100 to 125 kV are necessary to ensure ample film density with radiation times within the limits of tolerance. This, however, reduces the picture contrast, which in the case of sagittal skull roentgenograms can hardly bear any losses. However, notwithstanding the difficulties experienced up to the present, serial angiograms in the sagittal direction are a definite possibility. The question then remains as to whether such angiograms are actually necessary from the clinical point of view. As a matter of routine we take serial angiograms in a lateral direction only and supplement them by sagittal single shots.

A further possibility of improvement seemed to be afforded by the fact that, as stated at the commencement, the distinction of detail attainable with the Skull-Odelca is practically only limited by the resolving power of the fluorescent screen, and under these circumstances any unsharpness due to the mirror optics is of no significance, in spite of the very high luminosity of this camera. We therefore considered it a reasonable proposition to make the individual unsharpness factors take more equal shares in bringing about the total unsharpness (BOUWERS' 'Law of Equality' (1) (3)). A discussion of this state of affairs with Professor BOUWERS led to the development of a Skull-Odelca having mirror optics of 1.8 to 2 times greater luminosity (G. R. A. = 1 : 0.58) than at present. Outwardly it differs from the present camera by its very large mirror.

Even with this exceedingly high luminosity, the share taken by the objective in bringing about the total unsharpness is still less than the share taken by the fluorescent screen. The deterioration of the resolving power, and of the resulting detail under the subjective conditions of observation, for the purpose of diagnostic interpretation is so slight that it does not assert itself to any extent.

Our assumption has therefore been manifestly confirmed; the increase of luminosity by nearly 100 % hardly causes any appreciable loss on the other side. The gain, however, is now available and may at will be employed as reserve in individual cases, where it proves necessary

or appears desirable. In any case the amount of radiation required for the film density is almost halfed. As compared with direct large-size roentgenograms, the taking of a middle-size roentgenogram thus no longer requires a 3 to 5-fold amount of radiation but, on an average, only a 2-fold amount.

If the reserve is used for shortening the exposure time, the tube load diminishes to the same extent, so that no further problem is presented in this respect. It is even possible, when necessary, for the total number of pictures of a series to be considerably increased without any risk for the tubes. As a result of the shorter exposure times the already insignificant motion blur is also very much reduced. For angiocardiography of children, for which the Skull-Odelca is particularly well adapted on account of its advantageous screen size, this fact is of paramount importance. On the other hand, in special cases where this may be considered desirable, the possibility is afforded of operating with a lower voltage for the intensification of contrasts while maintaining the same exposure time, etc.

Finally, with the new camera one would naturally like to improve the detail by utilising the gain of luminosity of the objective so as to use a screen of finer grain but lower luminosity and possessing a better resolving power. However, if indeed any improvement can be achieved in this way, this possibility is necessarily confined to very narrow limits. It must be remembered that the increase of luminosity of the objective was only achievable on account of the predominant unsharpness due to the fluorescent screen, which was hitherto inevitable; it would be preposterous as a secondary aim to deprive the new objective of the very feature that justifies its existence.

The reduction of the amount of radiation by the use of the new camera naturally makes for easier protection against radiation and provides ample safety for the operating staff. Of course, it is still necessary for the usual protective measures to be applied in a most conscientious manner and for the relevant regulations to be carefully observed. This, however, applies in general to all serial roentgenography.

SUMMARY

A special Skull-Odelca, which has been developed in collaboration with BOUWERS (Delft), is described. By its use the problems of obtaining serial cerebral angiograms by means of fluorography on medium-sized film may be considered solved. The many advantages of the new camera are pointed out and discussed.

ZUSAMMENFASSUNG

Eine spezielle Schädel-Odelca, die in Zusammenarbeit mit BOUWERS (Delft) entwickelt worden ist, wird beschrieben. Bei Benutzung dieser Methode darf das Problem,

Serienaufnahmen von cerebralen Angiographien mit Hilfe von Schirmbildsaufnahmen auf Filmen mittleren Formates zu machen, als gelöst betrachtet werden. Die zahlreichen Vorteile dieser neuen Kamera werden hervorgehoben und diskutiert.

RÉSUMÉ

L'auteur décrit une caméra Odelca-cranienne spéciale qui a été mise au point en collaboration avec BOUWERS (Delft). On peut considérer que son emploi résout les problèmes que pose l'obtention d'angiographies cérébrales en série par radiophotographie sur film de format moyen. L'auteur examine et fait ressortir les nombreux avantages de cette nouvelle caméra.

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FROM THE DEPARTMENT OF NEUROSURGERY, ST. GEORGE'S HOSPITAL, LONDON, ENGLAND

SUBARACHNOID HAEMORRHAGE

by

L. S. Walsh

This paper will deal with the findings in 461 cases of subarachnoid haemorrhage, with special reference to those in which no abnormality was shown by bilateral carotid arteriography. This series includes all the cases of subarachnoid haemorrhage admitted to the neuro-surgical department of St. George's Hospital, under the care of Mr. WYLIE MCKISSOCK and Mr. VALENTINE LOGUE up to the end of March, 1954. The findings are summarised in the table below.

Table

Findings in 461 Cases of Subarachnoid Haemorrhage

ARTERIAL ANEURYSM	249 = 54 %
ARTERIOVENOUS MALFORMATION	53 = 11.5 %
CEREBRAL AND CEREBELLAR HAEMORRHAGE	35 = 7.5 %
NO LESION SHOWN	124 = 27 %

Cerebral and Cerebellar Haemorrhage. These are patients in whom an intracerebral or an intracerebellar haemorrhage had occurred in association with a subarachnoid haemorrhage, and in whom no vascular abnormality has been shown. Most, but not all of these patients were hypertensive or arteriosclerotic, and in the older age group. It is common to exclude these cases when considering spontaneous subarachnoid haemorrhage, but I have included them as I think that often they cannot be distinguished on clinical grounds, sometimes not even by arteriography. I do not think that this small number represents the true proportion of such cases which show signs of a subarachnoid haemorrhage, since many patients thought to have an arteriosclerotic, or hypertensive haemorrhage are not referred

Supported by a grant from St. George's Hospital, London.

to a neuro-surgical department. Also, many patients who are referred have mainly symptoms of an intracerebral haemorrhage, and a lumbar puncture is not performed.

Patients in whom no lesion was shown. From 124 cases, 93 have been chosen for further consideration. These 93 are all patients in whom the diagnosis of subarachnoid haemorrhage was proven by lumbar puncture, and in whom bilateral carotid arteriography was performed. The reasons why bilateral carotid arteriography was not performed in the remainder are many. Some of the patients refused to have the examination; others were seen long after the subarachnoid haemorrhage, and further investigation was not considered justified at the time; some were admitted to hospital many years ago, before routine, percutaneous, arteriography was performed.

Of the 93 patients, 22 had, in addition, vertebral arteriography. It is not our custom to perform vertebral arteriography routinely in cases of subarachnoid haemorrhage. This investigation is usually only performed if there are special indications. The patients have been followed up for periods of from one to 11 years, with an average in the survivors of just over three years.

Fifteen of them have since died: 6 of a recurrence of haemorrhage, an aneurysm being found at post-mortem examination; 5 of a recurrence of haemorrhage; no aneurysm was found at post-mortem examination; 2 of other causes; in 2 cases the cause of their death is not known.

Thus, in six patients an aneurysm was found. The first five of these six patients were very ill, when admitted to hospital, and four of them died within a few days of admission. The fifth died three weeks after his last haemorrhage. Of the five, three had the artery from which the aneurysm arose visualized but the aneurysm did not show. The other two, who did not have vertebral arteriography, did not have the artery from which the aneurysm arose, visualized. The sixth patient, who had bilateral carotid arteriography, which filled the left posterior cerebral artery, was discharged from hospital and remained well for eight years, when she had another haemorrhage which proved fatal. Autopsy showed a ruptured aneurysm on the left posterior cerebral artery with an intracerebral haemorrhage.

Five patients suffered from a fatal recurrence of haemorrhage and no aneurysm, or other vascular abnormality was found in the brain. Of these patients, three were hypertensive. It is possible that at least some of them had an aneurysm or angioma, which was not demonstrated at autopsy. Of the two patients who died from other causes, one died of cardiac failure and no post-mortem examination was performed. The

other died following an operation for hypertension. Post-mortem examination showed atheroma of the cerebral vessels and small cystic cavities in the cerebral hemisphere — evidence of old haemorrhage. There was no evidence of recent haemorrhage. In addition the patient had chronic pyelonephritis.

Thus, in these 93 patients, 11 have died of recurrence of haemorrhage and 2 of causes unknown. Possibly 13 have died as a result of a recurrence of intracranial haemorrhage. On these, 2 are known to have had an aneurysm arising from an artery, which was not shown by arteriography. Four had an aneurysm which was not shown by arteriography, although the vessel from which the aneurysm arose was shown. Of the 5 patients in whom the abnormality causing the haemorrhage was not shown at post-mortem examination, 3 had an intracerebral haemorrhage into a cerebral hemisphere where an aneurysm or angioma might have been expected to be filled by carotid arteriography, and 2 had a subarachnoid haemorrhage, the source of which was not found.

Six of the 93 patients were very ill on admission to hospital and died within a short while. The remaining 87 patients were discharged, well, from hospital and of these there were 5 who definitely, and 2 who possibly died as a result of a recurrence of subarachnoid haemorrhage, making a total of 7, or approximately 8 %.

This figure of 8 % can be compared with 20 %, the mortality for subarachnoid haemorrhage in general given by most authors, in patients who have been discharged well from hospital. This supports, I think, our impression that the prognosis in patients in whom no abnormality is shown is better than for subarachnoid haemorrhage in general.

Finally, I would like to describe some cases of interest. These cases are not all from the above series, as some of them have been seen since March, 1954. In addition to the common causes of subarachnoid haemorrhage we have found the following conditions in patients being investigated for subarachnoid haemorrhage.

Cerebral Embolus. A female, aged 38, who was not hypertensive had had a subarachnoid haemorrhage a few days before admission. Bilateral carotid arteriography showed no abnormality, apart from poor filling of the right middle cerebral artery. The patient died. Autopsy showed an embolus in the right middle cerebral artery with oedema and congestion of the right cerebral hemisphere. There was thickening of, and vegetation on the aortic valves.

Spinal Vascular Malformation. A female, aged 52, with a normal blood pressure had had two subarachnoid haemorrhages in the ten days before admission. Bilateral carotid arteriography and vertebral arteriography showed no abnormality. Over the next few days she had four further haemorrhages. In some of the attacks the pain started in the back. A spinal angioma was considered, and a positive contrast myelogram was performed. This showed a number of irregularities in the cervical and dorsal regions, but it was not felt that they showed definite evidence of an angioma of the spinal cord. Her

condition continued to deteriorate, and she died. At post-mortem examination no vascular abnormality was found in the brain, but a diffuse arteriovenous malformation of the spinal cord was found, which had caused the subarachnoid haemorrhage.

Cerebral Tumour. A female, aged 45, who was mildly hypertensive, had had a first subarachnoid haemorrhage six months before. She had a second haemorrhage one day before admission. Bilateral carotid arteriography showed slight displacement to the left of the anterior cerebral arteries, but no other abnormality. A ventriculogram showed a filling defect in the floor of the right lateral ventricle, in the region of the Foramen of Monro. The patient died, and at post-mortem examination a tumour, 3 cm in diameter, was found on the floor of the right lateral ventricle. Microscopical examination showed it to be an astrocytoma (Grade III) with extensive haemorrhage into the tumour tissue.

Cerebellar Infarct. A female, aged 48, who was hypertensive, had two days before admission developed a severe headache and had become very drowsy. Lumbar puncture showed slightly blood-stained, xanthochromic cerebro-spinal fluid. Bilateral carotid arteriography, which filled both posterior cerebral arteries, showed no abnormality. As the patient's condition was deteriorating, and she showed signs of medullary compression, a ventriculogram was performed. This showed signs of a space occupying lesion in the left cerebellar hemisphere. A craniotomy was performed, and the lower, lateral part of the left cerebellar hemisphere, which was necrotic, congested and infarcted, was removed. There was no evidence of a haemorrhage into the cerebellar hemisphere, and no vascular abnormality was found. The patient improved after this and was discharged well from hospital.

Three cases were examined with arteriography, which showed evidence of an intra-cerebral haematoma but did not show the source of the haemorrhage.

A male, aged 25, who was not hypertensive, had had a subarachnoid haemorrhage one week before, since when he had been comatose, with a left hemiplegia. Bilateral carotid arteriography showed no aneurysm, but the anterior cerebral arteries were displaced to the left. A ventriculogram showed the ventricular system displaced to the left and a cavity in the right frontal region which communicated with the ventricles. A craniotomy was performed and the haematoma evacuated. This revealed a large, thrombosed aneurysm 3 × 2 cm in size, arising from the termination of the right internal carotid artery. This was packed and the patient has remained well.

A man, aged 49, who was hypertensive. He had had a subarachnoid haemorrhage, and he had a left-sided hemiplegia. Bilateral carotid arteriography showed some displacement of the anterior cerebral artery to the left but no other abnormality. A ventriculogram showed displacement of the ventricular system and a cavity in communication with the lateral ventricle. The haematoma was evacuated, but no vascular anomaly was found. The patient died, and post-mortem examination showed cerebral arteriosclerosis, the haematoma cavity extending into the internal capsule, but no aneurysm or vascular malformations were found.

A female, aged 38 years, who had had a subarachnoid haemorrhage three weeks before admission. Bilateral carotid arteriography showed an upward and inward displacement of the left middle cerebral artery, with very slight displacement of the anterior cerebral artery to the right. Vertebral arteriography showed no abnormality. A craniotomy was performed, and a large temporo-parietal intracerebral haematoma was evacuated. On the floor of the cavity was a thrombosed angioma, supplied by two arteries

on its deep aspect and with two veins running from its anterior aspect into the sphenoparietal sinus. The patient has remained well.

SUMMARY

A review of 461 cases of subarachnoid haemorrhage with special reference to those in which no abnormality was shown by bilateral carotid arteriography.

ZUSAMMENFASSUNG

Der Verfasser gibt eine Übersicht über 461 Fälle mit Subarachnoidalblutungen. Hierbei werden die Fälle besonders berücksichtigt, bei denen die doppelseitige Carotisangiographie keine pathologischen Befunde zeigte.

RÉSUMÉ

Étude de 461 cas d'hémorragie sous-arachnoidienne, et plus particulièrement de ceux où l'artériographie carotidienne bilatérale n'a pas montré d'anomalie.

THE DEPARTMENT OF NEUROSURGERY (DIRECTOR: KRISTIAN KRISTIANSEN),
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A CLINICAL AND RADIOLOGIC EVALUATION OF SPONTANEOUS SUBARACHNOID HEMORRHAGE

by

Kristian Kristiansen

Spontaneous subarachnoid hemorrhage is a sign either of disease of the central nervous system or of a few generalized pathologic conditions associated with hemorrhagic diathesis, in particular infections and blood dyscrasias. The recent interest in this relatively rare sign which some few years ago was considered to lie purely within the realm of medicine, is primarily due to radiologic diagnostic procedures. Furthermore, the possibility of an *in vivo* diagnosis of an intracranial arterial aneurysm as a frequent cause of spontaneous subarachnoid hemorrhage has opened the gate for surgical treatment in a certain percentage of the cases. Our tribute is due to WALTER DANDY who in so many ways has enriched neuroradiology and neurosurgery through his unusual diagnostic and therapeutic versatility.

Despite all that has been written during the past ten years since the publication of Dandy's monograph *Intracranial Arterial Aneurysms*, there are still many controversial points to be discussed regarding diagnosis and treatment in patients with subarachnoid hemorrhage. The statistic evaluations are too often based on selected materials, the mortality figures frequently giving an impression of a biased view on the therapeutic possibilities.

To provide a personally investigated material of spontaneous subarachnoid hemorrhages close cooperation has been established with all the Departments of Ullevål Hospital, Oslo, which, with its 2,600 beds, is one of the larger city hospitals and university clinics in Europe. During the five-year period 1950—1954 all patients presenting this syndrome have been subjected to a thorough examination including, if possible and advisable, one or more cerebral angiographies. The 130 patients

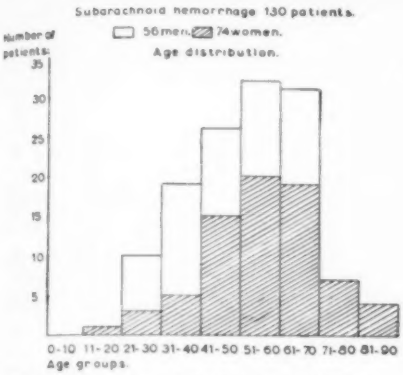

Diagram 1. Age distribution in 130 patients with subarachnoid hemorrhage.

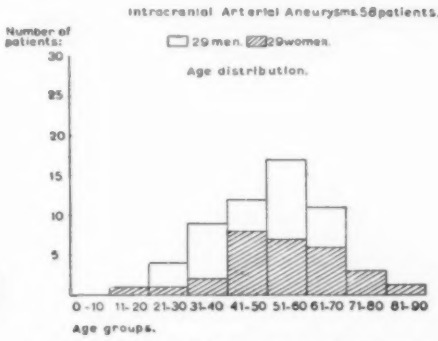

Diagram 2. Age distribution in 58 patients with intracranial arterial aneurysms.

constituting the material probably represent a number close to all cases with subarachnoid hemorrhage among the 400,000 inhabitants of Oslo, thus giving an approximate frequency of three cases per year per 50,000 of the living population. Fifty-nine of the 130 patients died, *i. e.* 45 per cent. The age distribution (Diagram 1) shows a striking prevalence of male patients in the younger age groups of 20 to 40 years. For comparison the age distribution among the 58 patients with intracranial arterial aneurysms is shown in Diagram 2.

The causes of the subarachnoid hemorrhage are presented in Table 1. In spite of an extensive use of cerebral angiography we could find no definite cause for the bleeding in 53 of our 130 cases. Thirty-five of these 53 cases had been subjected to angiography and in 8 cases even autopsy was performed without any evidence of the source of the hemorrhage. Sixteen of the 53 patients had arterial hypertension, 1 had previous syphilis, 1 previous syphilis with severe alcoholism, and 1 had congenital heart failure, all of which conditions may have been a contributing cause but not the decisive factor in the meningeal bleeding.

The fact that the cerebral angiography fails to give the etiologic diagnosis in a high percentage of cases of subarachnoid hemorrhage should warn against an uncritical use of the method, particularly as it is not completely void of danger for the patient. In my own fifteen years' experience with percutaneous cerebral angiography I have seen very few, but nevertheless some deplorable, complications. At our hospital we feel that many of the reported transitory hemiplegias and other accidents are caused by an inadvertent production of a dissecting aneurysm of the carotid artery in the neck by performing the injection through a sharply pointed cannula; this has been made clear by KJELL LIVERUD of our

Table 1

Subarachnoid hemorrhage, 130 cases; causes of hemorrhage

	Number	
Arterial aneurysms	58	
Unknown cause	53	(hypertension 16)
Arteriosclerosis of brain vessels	5	(hypertension 1, polycystic kidney 1)
Cerebral hemorrhage	7	
Arterio-venous fistula or aneurysm	3	
Intracranial tumor (melanoma)	1	
Renal tuberculosis with reduced kidney function	1	
Cerebral thrombosis	1	
Carcinoma of hepatic duct, jaundice	1	
Total	130	

Department of Radiology, whose introduction of the direct percutaneous polyethylene catheter method in carotid angiography is in my opinion the most important addition to our technique since the beginning of 1940. He has now a material of about 250 catheter angiographies since May 1954.

Cerebral angiography has been performed in 85 of the 130 cases. Three were totally unsuccessful. The distribution is shown in Table 2.

Table 2

Subarachnoid hemorrhage, 85 cases; distribution of cerebral angiographies

	Number of Cases	
Right carotid artery	29	(1 unsuccessful)
Left carotid artery	20[1]	(2 unsuccessful)
Bilateral carotid artery	32[2]	
Bilateral carotid artery + vertebral artery	2	
Unilateral carotid art. + vertebral artery	2[3]	
Total	85	

[1] One with both contralat. carotid and vertebral filling by compression of the r. carotid during injection.

[2] Three unsuccessful on one side (one right, two left).

[3] Plus one in which the vertebral angiography was unsuccessful (to be found under left carotid).

Several of the patients have been subjected to more than one angiographic examination. Many of the unilateral carotid angiographies have given information of the vascular system in both hemispheres when injection of the contrast medium was performed during digital compression of the contralateral carotid artery in the neck. This procedure is a routine one and practically never fails with the polyethylene catheter method.

Important in this connection are our reasons for *not* performing angiography in the rest of our material or 45 patients. Table 3 gives this information.

Table 3

Subarachnoid hemorrhage, 45 cases; reason for omitting angiography

	Number
Died before admission or within a few hours afterwards	19
Poor general condition	13
Old age (above 70 years)	5
Patient or relatives declined angiographic examination	2
No cause stated	6
Total	45

Even with our rather active diagnostic attitude it will be seen that we have consciously refrained from the angiographic examination in at least 18 cases, or about 15 per cent, because of poor general condition or old age. In 19 cases, or another 15 per cent, the patient was dead before or died shortly after admission; this group is beyond either conservative or surgical therapy and in any discussion of the advantage of surgical interference over conservative treatment this group must be excluded. The same pertains to the age group above 70 years, perhaps above 65 years, as surgical therapy on the cerebral vessels at this age will probably not be considered, except in selected cases. Most patients with multiple aneurysms must also be excluded.

Table 4 gives some data on the 58 arterial aneurysms in our material.

Table 4

Intracranial arterial aneurysms	58 patients	(29 men, 29 women)
Died	35 patients	(60 per cent)
Aneurysm demonstrated by		
Angiography	24	(3 multiple)
Autopsy	22	(3 multiple)
Angiography + Autopsy	12	
Total	58	

Of the 35 patients who died, thirteen did so before or immediately after admission, seven died within one week, and five within two weeks after the onset of symptoms.

The sex distribution is even, in contrast to the more frequent occurrence among females of subarachnoid hemorrhage from other causes. Thirty-five of the 58 cases with aneurysms died. This is a higher mortality rate than subarachnoid hemorrhages show as a whole. If due consideration is given to the groups of patients dying either before or immediately after admission, and those dying within one to two weeks after admission, all of whom are to be excluded absolutely or relatively from

those under discussion for surgical treatment, we feel that any immediate postoperative mortality rate must be low, probably below 5 per cent, to justify radical operations on intracranial aneurysms. No attempt is made to evaluate the long term mortality rate due to recurrent ruptures of the aneurysmal sac in a conservatively treated material. From the beginning of 1955 we have adopted a radical surgical attitude towards intracranial aneurysms with the guidance as to permissible mortality which the present material has provided.

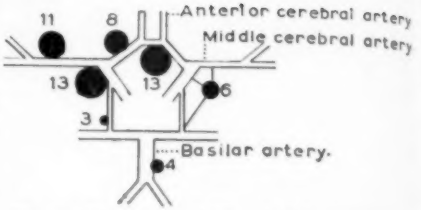

Fig. 1. Situation of 58 arterial aneurysms.

It is necessary to subdivide the aneurysms into groups with consideration to the different problems as to diagnosis and treatment. Fig. 1 demonstrates the sites of the aneurysms in this material.

The frequent combination of aneurysms with other vascular anomalies is well known. According to MAYNARD COHEN's and my own investigations on clinical and autopsy material, approximately half of the aneurysms situated on the anterior communicating artery will exhibit associated anomalies of the anterior cerebral circulation. Coexistence of these two lesions is of practical importance when surgical procedures are considered. Adequate evidence of bilateral, not only anatomic, but also

Fig. 2. Left carotid arteriogram with bilateral filling of anterior cerebral arteries and aneurysm.

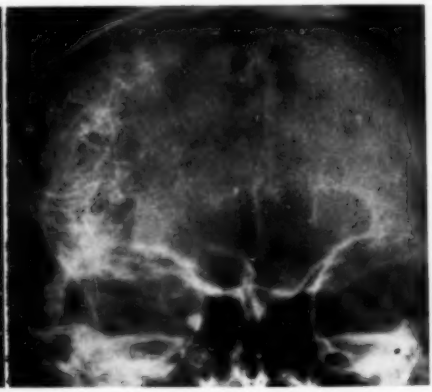

Fig. 3. Same case. Right carotid arteriogram. No contrast medium in anterior cerebral system.

Fig. 4. Same case. Pathology preparation of circle of Willis. Thread-like right anterior cerebral artery.

functional, patency of the anterior cerebral artery is of particular significance. Figs. 2, 3, and 4, taken from a patient who died of recurrent hemorrhage serve to illustrate this point. The pathologic specimen seemed to exclude the possibility of surgery.

The detailed clinical and radiologic study of each case of subarachnoid hemorrhage is a prerequisite for more extensive knowledge of the etiology and therapy of the underlying disease. Cerebral angiography is an indispensable diagnostic aid but should be used with caution especially during the first two weeks following the hemorrhage, in old patients, and in patients in poor general condition; this is mainly because immediate surgery is precluded and because a diagnostic procedure not aiming at therapy should be avoided.

SUMMARY

The author reviews a material of 130 cases of spontaneous subarachnoid hemorrhage collected in the period 1950—1954, with special reference to cerebral angiography, which was performed in 85 of the cases. The indications for omitting the procedure and the necessity for performing it with due caution in certain cases are discussed.

ZUSAMMENFASSUNG

Der Verfasser unterzieht ein Material von 130 Fällen mit spontaner Subarachnoidalblutung, das während des Zeitraumes 1950—1954 eingesammelt wurde, einer kritischen Prüfung; hierbei wird besonders die cerebrale Angiographie berücksichtigt, die in 85 Fällen benutzt worden ist. Die Indikationen für die Unterlassung der Prozedur und die Notwendigkeit, sie in gewissen Fällen mit gebührender Vorsicht durchzuführen, werden besprochen.

RÉSUMÉ

L'auteur passe en revue une série de 130 cas d'hémorragie sous-arachnoïdienne spontanée rassemblés dans la période 1950—1954 et traite spécialement la question de l'angiographie cérébrale qui a été pratiquée dans 85 de ces cas. Il examine les contre-indications de cette technique et la nécessité de l'exécuter avec prudence dans certains cas.

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CEREBRAL ANGIOGRAPHIC STUDIES FOLLOWING SURGICAL TREATMENT OF INTRACRANIAL ANEURYSMS

Angiographic Evaluation of Results

by

Lester A. Mount and *Juan M. Taveras*

It is not difficult to obtain follow-up angiograms in patients who have undergone surgical treatment of intracranial aneurysms when patients are prepared for it before the initial operation. What happens to the aneurysm following internal carotid ligation, and other types of ligation, and how does the cerebral circulation re-establish itself, are questions which must be answered if one attempts to ascertain the value of the surgical treatment of aneurysms, and if one hopes to learn to avoid the complications which arise from faulty or insufficient collateral circulation.

In an effort to obtain an answer to these and other questions we have become engaged, in the last few years, in an evaluation program in which patients are brought back for cerebral angiography from several weeks or months to a few years following the initial surgical intervention. This communication represents a preliminary report of our findings.

Material

The group studied so far consists of 42 patients who have undergone several types of surgical treatment of intracranial aneurysms in various locations. There were 32 patients who had aneurysms of the internal carotid artery, 7 who had middle cerebral, 8 anterior communicating

artery aneurysms, and 1 at the pericallosal artery. Six patients had two aneurysms.

To date we have studied 27 patients following ligation of the internal carotid artery in the neck. Three patients had ligation of the common carotid artery. Four patients had intracranial internal carotid artery ligation or clipping of the aneurysm in addition to ligation in the neck, and there were 8 patients in whom only intracranial clipping of the aneurysm or of the feeding vessel was performed. Three patients had the internal carotid artery clamped, followed later by common carotid ligation when the clamp was found to be open.

Method

Postoperative angiography was carried out from 10 days to 17 months after the original operation, the average interval was 5.4 months, excluding four cases in whom the interval was two, six, six and a half, and seven years.

Bilateral carotid and vertebral arteriography was performed when necessary to demonstrate the status of the occluded artery, the aneurysmal site, and the artery from which the aneurysm arose. In many of the cases, unilateral or bilateral carotid angiography was sufficient. Serial exposures were made at 0.5 second intervals in all the cases. This afforded an excellent opportunity to study the collateral circulation of the brain which will be the subject of a subsequent publication.

The injection in the post-operative angiograms was made below the occluding clamp or metal band whenever possible. Other times the needle was inserted above the clamp, particularly when the common carotid artery had been ligated. The aneurysmal site was sometimes shown upon injection of the ligated side by making the injection above the clamp or by means of collateral circulation between the external and internal carotid arteries through the ophthalmic artery. In some cases, percutaneous puncture of the artery on the ligated side was not possible. The aneurysmal site was visualized in most cases by injecting the opposite carotid or the vertebral artery and we interpreted failure of the aneurysmal sac to show on the angiogram as most probably due to thrombosis within the aneurysm.

Analysis of Cases

Status of the clamp. In the course of studying these patients we found that in some of the cases the arterial lumen was not actually occluded at the site of the attempted ligation. This is particularly striking in the patients in whom a tantalum band was used to ligate the internal carotid artery. In 6 patients so treated the artery was found to be patent in 5

(see fig. 1). It is not possible to tell whether the artery was completely occluded in the beginning, and later became recanalized, or whether it was never completely obstructed by the metal band. In one instance in this series of patients, recanalization actually took place outside of the tantalum band, which indicates that the wall of the artery was probably cut at one point at the time of the application of the band. The artery was found to be incompletely occluded in a few instances (five) after application of a Selverstone clamp in our earlier cases. This is probably due to the fact that the arterial wall becomes atrophic or thinner at the site of the application of the clamp, and so, after an unknown period of time, the blood stream becomes re-established. In some cases the clamp may never have been completely closed. In our more recent cases we have obtained permanent ligation by giving the clamp a final tightening, which we feel injures the intima and provokes a local thrombosis, in addition to allowing for any arterial wall thinning that may take place. Thrombosis of the internal carotid artery does not usually occur following ligation, except in the area adjacent to the clamp. But when the common carotid artery is ligated, it seems to become thrombosed above the occluding clamp up to the bifurcation and occasionally beyond it, and often thrombosed below the clamp, for we have been unable to tap the artery proximal to the clamp, or to feel pulsation in the artery in some cases of common carotid ligation. We have also had occasion to verify this at the operating table in several patients in whom the common carotid artery was ligated one week prior to ligating the internal carotid artery. Out of 28 cases, the Selverstone clamp was found to be actually occluding the vessel in 15 (one case required re-tightening), in 4 cases it was open, in 6 cases it was released, and in the remaining 3 patients the status of the clamp could not be ascertained.

Fig. 1. Post-ligation angiogram performed five years after application of a tantalum band to internal carotid artery. Band fails to occlude vessel.

Status of the aneurysm. We made a great effort in trying to demonstrate the aneurysmal site in order to determine, if possible, what had actually taken place in the aneurysmal sac. Let us consider first the patients in whom permanent ligation was accomplished (16 cases). In 7 patients the aneurysmal sac could not be demonstrated; in 3 cases the sac had become considerably smaller and in 2 instances it remained unchanged in size.

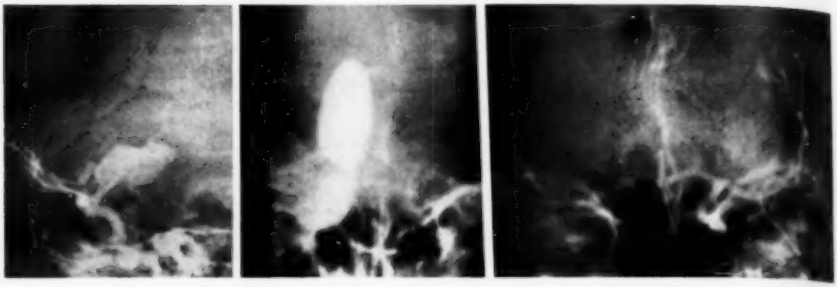

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Fig. 2. a) and b) Large internal carotid artery aneurysm. c) Angiogram performed five months after internal carotid ligation shows filling from opposite side. Sac is no longer demonstrable.

In no case was it seen to become larger. In 4 patients the site from which the aneurysm arose could not be shown adequately. Location seems to be of great importance, for the 7 cases in whom the aneurysm was presumably thrombosed were all internal carotid aneurysms (see fig. 2). There were 6 instances of middle cerebral aneurysm, and in none of these did the aneurysm fail to fill after carotid ligation, although it was smaller in 3 (see fig. 3). One of this latter group of cases is extremely interesting because the first post-operative angiogram revealed that the clamp was not occluding the internal carotid artery; the aneurysmal sac was unchanged or larger in the examination made six months after the first

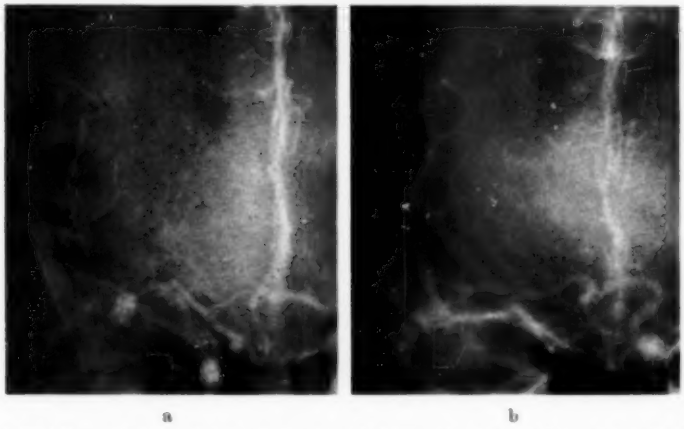

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Fig. 3. a) Middle cerebral artery aneurysm. b) 4 months after internal carotid ligation; aneurysmal sac is considerably smaller than originally.

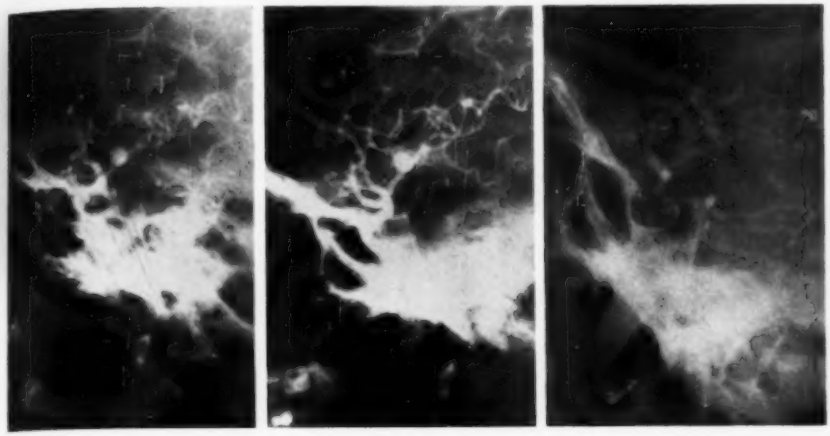

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Fig. 4. a) Middle cerebral artery aneurysm. b) Repeat angiography 6 months after application of a Selverstone clamp. Clamp has not occluded the artery and aneurysm is unchanged in size or configuration. c) Clamp was re-tightened and repeat angiography 2 months later reveals that clamp is closed. Aneurysmal sac is smaller but middle cerebral branches of approximately same size. Filling was obtained by way of the vertebral circulation.

attempt at ligation. The clamp was re-tightened this time, and another angiogram carried out two months later showed that the occlusion was now complete and the aneurysmal sac smaller in volume (see fig. 4), but the feeding vessels were of the same caliber. In the last angiograms the sac filled by way of the vertebral circulation. This points out that ligation had a favorable effect upon the aneurysmal sac, at least allowing the walls to become thicker and the lumen to become smaller. It is doubtful that the reduction in size is due to a permanent lowering of the blood pressure allowing the aneurysmal sac to shrink by its own elastic pressure.

There were 15 patients in whom the internal carotid artery was found to be incompletely occluded; this includes those in whom the clamp had to be re-opened because of evidence of insufficient collateral circulation. The aneurysmal sac could not be demonstrated in 4 of these cases. It was unchanged in size or configuration in 5, smaller in 4, and larger in 2 instances. It is not possible to tell how many of these patients had temporary interruption of blood flow through the artery. In this group of 15 patients there are 6 cases in whom we know that complete occlusion of the artery was produced at the initial operative intervention, and the clamp had to be released. These patients, therefore, had temporary liga-

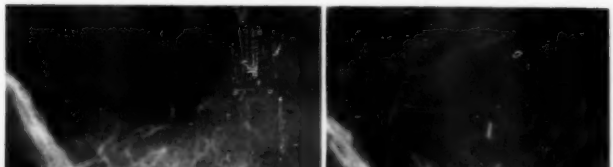

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Fig. 5. a) Pre-operative angiogram. b) Post-operative angiogram 5 months after intracranial approach and packing of aneurysm with muscle. Only a very small outpouching remains at site of aneurysm.

tion lasting from 30 minutes to 12 hours. In these six patients the aneurysm was not visible in two and unchanged in three. Of the two patients, in whom the aneurysm was not visible, the clamp was closed for two hours in one, and for four hours in the other.

In the entire series, there were 12 patients in whom a repeat angiogram had to be carried out either because additional data were required before definitive treatment, or because treatment had to be postponed for one or several weeks or months due to the poor condition of the patient at the time of the initial study. The time interval between the first and the second angiogram ranged from 2 weeks to 15 months; the average time was 3 months. In addition there were two patients studied only for the purpose of determining the status of the aneurysm in whom no surgical treatment was contemplated. In this entire group of 14 patients, the aneurysm was invariably of the same size and shape as in the first angiogram, and it was larger only in one case. This certainly points out the value of surgical treatment of intracranial aneurysms. Post-operative angiography showed the aneurysm to be no longer demonstrable in one patient in this group, and in three others it was smaller.

We had occasion to study several patients in whom complications arose as a result of ligation requiring loosening of the clamp. One of these patients developed a hemiplegia, which did not clear completely in spite of the fact that the clamp was re-opened promptly. The angiogram revealed thrombosis of the middle cerebral artery and accompanying spasm of the adjacent major arteries. The aneurysmal sac was not demonstrated.

There were 8 patients who underwent intracranial approach on the aneurysm. Two of these had the aneurysmal sac packed with muscle and the aneurysm was not visible in either (see fig. 5). Five patients had clipping of the feeding vessel, or of the neck of the aneurysm, and in one of these the clips were found to have re-opened on repeat angiography. In another patient, clipping could not be accomplished and the sac was merely wrapped with muscle; the post-operative angiogram revealed no change in the aneurysm. In the other 4 patients the sac was no longer demonstrable. There were 4 patients in whom the internal carotid artery was ligated in the neck, as well as intracranially, and the aneurysmal site could not be demonstrated in any of them, as might have been anticipated (see Table).

Table

Type of surgical intervention	Number of cases	Clamp				Aneurysm		Aneurysmal area
		open	released	not seen	closed	did not fill	filled	not seen
Internal carotid ligation	27*	8**	6	2	11	10	14	3
Common carotid ligation	3	1		1	1	1	1	1
Cervical and intracranial internal carotid ligation	4				4			4
Intracranial approach: clipping	5	1				4	1	
Intracranial approach: packing with muscle.....	2					2		
Intracranial approach: muscle wrapped around sac	1						1	
Common carotid ligation preceded by unsuccessful internal carotid ligation (included also in group 1) ...	2				2		2	
Total A — Cervical ligations	30	9	6	2	11	11	15	4
Total B — Intracranial approach	12	1				6	2	4

* Five of these patients and one of the common carotid ligations had a tantalum band. In the remainder a Selverstone clamp was used.

** A ninth case was re-tightened after it was found to be open and is included among the "clamp closed" group.

Conclusions

This study demonstrates that ligation of the internal carotid artery in the neck is of value in the treatment of intracranial aneurysms. Permanent ligation of the artery is difficult to obtain with safety, and the

Selverstone clamp is probably the safest available method of producing occlusion of the vessel. With careful post-operative follow-up the clamp can be re-opened as soon as the patient develops any complications. Only 3 patients in this series of 42 developed hemiplegia which did not clear completely, following release of the clamp, and in 1 patient we were able to show angiographic evidence of thrombosis of the middle cerebral artery.

The aneurysmal sac was no longer demonstrable in 11 out of 30 patients in whom either a permanent or temporary ligation of the internal carotid artery was accomplished, but the proportion of presumably thrombosed aneurysms was higher (7 out of 12) in the patients in whom the internal carotid artery was shown to be completely occluded. The location of the aneurysmal sac is very important, for all of the cases in whom the sac was no longer demonstrable were internal carotid artery aneurysms. In the 6 cases of middle cerebral artery aneurysm, the sac was demonstrable on repeat angiography, although it was considerably smaller in 3 of the cases.

Of great interest is the group of 14 patients in whom repeat angiography prior to surgical treatment revealed no change in the aneurysmal sac in every instance, but one which was enlarged. One of these aneurysms was not demonstrated in the post-operative angiogram and 3 had diminished in size. Spontaneous thrombosis of an aneurysm is known to occur, but it would appear, as a result of this study, that once the aneurysm is demonstrated angiographically it is unlikely for it to become spontaneously thrombosed within a relatively short period of time.

Intracranial approach of aneurysms with clipping of the aneurysmal sac, or of the feeding vessels when feasible, is the best method of treatment. It was found to be successful in eliminating the aneurysmal sac from circulation in all except one instance in which the silver clips were found to be open and the aneurysm unchanged. Packing of the sac with muscle was done in two patients in this group, and post-operative angiography failed to demonstrate the aneurysmal sac in both. Packing muscle around the sac in one instance showed no change in the aneurysm three and a half months later.

SUMMARY

This arteriographic study demonstrates that ligation of the internal carotid artery is of value in the treatment of intracranial aneurysms. The aneurysmal sac was no longer demonstrable in 11 out of 30 patients in whom either permanent or temporary ligation of the internal carotid artery was accomplished, but the proportion of presumably thrombosed aneurysms was higher (7 out of 12) in the patients in whom the internal carotid artery was shown to be completely occluded. So far in this follow-up study all of the presumably thrombosed aneurysms were in the internal carotid artery. When feasible, intracranial surgical approach, with clipping of the aneurysmal sac, or of the feeding vessels, is the best method of treatment.

ZUSAMMENFASSUNG

Diese arteriographische Studie zeigt, dass die Unterbindung der Arteria carotis interna für die Behandlung von intrakraniellen Aneurysmen von Wert ist. Das Aneurysmasäckchen war bei 11 von 30 Patienten, bei denen entweder permanente oder temporäre Unterbindung der Arteria carotis interna ausgeführt worden ist, nicht länger nachweisbar, aber das Verhältnis der vermutlich thrombotisierten Aneurysmen war bei den Patienten höher (7 von 12), bei denen die Arteria carotis interna völlig okkludiert war. Bisher gehörten in dieser Nachuntersuchung alle vermutlich thrombosierten Aneurysmen zur Arteria carotis interna. Das intrakranielle Angreifen des Aneurysmas mit Unterbindung des Aneurysmasäckchens oder der zuführenden Gefässe mit Klips ist, wenn es durchführbar ist, die beste Behandlungsmethode.

RÉSUMÉ

Cette étude artériographique montre que la ligature de l'artère carotide interne est utile dans le traitement des anévrysmes intracraniens. Il n'a plus été possible de visualiser le sac anévrysmal chez onze malades sur trente qui avaient subi une ligature permanente ou temporaire de l'artère carotide interne, mais la proportion des anévrysmes vraisemblablement thrombosés était encore plus élevée (sept sur douze) chez les malades dont l'artère carotide interne s'est révélée complètement obstruée. Jusqu'à maintenant, dans cette étude de l'évolution, tous les anévrysmes présumés thrombosés siégeaient sur l'artère carotide interne. Quand il est possible, l'abord chirurgical intracranien, avec clippage du sac anévrysmal ou des vaisseaux afférents, est la meilleure méthode de traitement.

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ATROPHY WITHIN THE BRAIN STEM AREA FOLLOWING INJECTION OF THOROTRAST INTO THE VERTEBRAL ARTERY

A report of a case

by

Tormod Hauge

The author's experience has been derived mainly from catheter vertebral angiography (HAUGE 1954) with Angiopac, Thorotrast, and various contrast media of the diodrast group. All these are frequently attended by clinical symptoms which again may be accompanied by disturbances of the cerebral electric activity, even in cases incompatible with a positive BROMAN and OLSSON test (BROMAN and OLSSON 1948, 1949; BROMAN, FORSSMAN and OLSSON 1950).

These clinical observations have been confirmed by the experimental work in animals by BLOOR, WRENN and HAYES (1951) who found that the EEG disturbances appeared before the tests became positive and that Thorotrast never produced EEG changes sufficiently marked to be accompanied by a positive test.

The following case, however, will show that in cases of advanced arteriosclerosis great risk is also attached to this contrast medium.

Case report

A male aged 63 with bulbar symptoms was considered to be suffering from a vascular lesion in the brain stem area. Six ml of Thorotrast were injected into the right vertebral artery. Three minutes later his bulbar state became markedly accentuated and he lost consciousness; tracheotomy was performed. The pupils reacted to light but the corneal reflexes were diminished. No response to painful stimuli to the face or other parts of body; hypotonic quadriplegia and all deep reflexes as well as the plantar reflexes absent. In spite of the patient being unconscious the EEG was normal; there was no

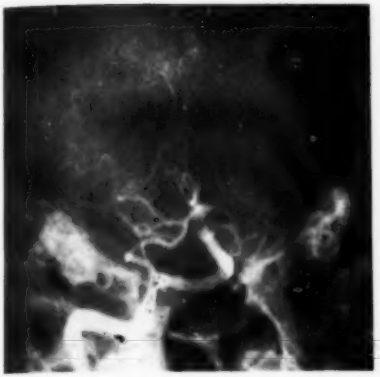

Fig. 1. Vertebral arteriogram. Brain stem area filled to level of superior cerebellar arteries.

Fig. 2. Base of brain. Extensive arteriosclerosis and organized saccular aneurysm in superior part of basilar artery obstructing passage to posterior cerebral arteries.

response to sound, smell or pain. The arteriogram (Fig. 1) revealed that the contrast medium had flushed the brain stem area to the level of the superior cerebellar arteries as no filling of the posterior cerebral arteries could be demonstrated. The clinical condition persisted unchanged for a year-and-a-half, when the patient suddenly died.

Autopsy (Fig. 2) revealed extensive arteriosclerosis of the vertebral arterial system with an organized saccular aneurysm in the superior portion of the basilar artery, ob-

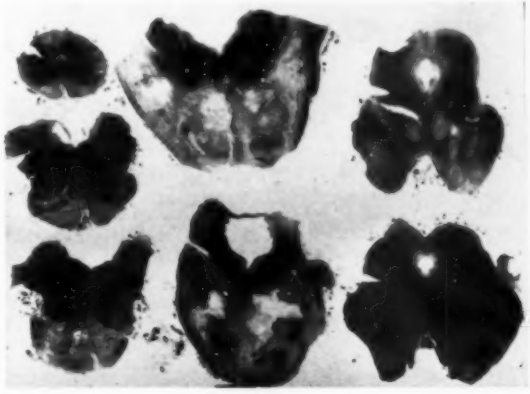

Fig. 3. Sections at level of medulla oblongata. Bilateral atrophy of pyramidal tracts, posterior fascicules, median lemnisci, cerebellar tracts, and whole pontine region with posterior part of mesencephalon including inferior colliculus.

structing the passage of water via the basilar artery to the posterior cerebral arteries, thus explaining the non-filling of these arteries in the arteriography. The main blood supply to the brain stem was derived from the right vertebral artery.

Sections (Fig. 3), stained with Weil's myeline stain (CHRISTIE-LOKEN), at the level of the medulla oblongata, revealed bilateral atrophy of the pyramidal tracts, the posterior fascicules, the median lemnisci, and the cerebellar tracts. The whole pontine region was almost completely destroyed, and there was atrophy of the posterior part of the mesencephalon including the inferior colliculus. The superior colliculus and the remaining part of the brain above this level showed normal staining. This fact was brought out by one of the sections of the hemispheres. The cerebellum showed almost complete degeneration (Fig. 4).

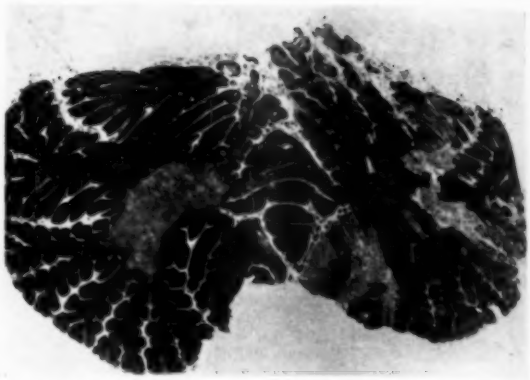

Fig. 4. Cerebellum showing almost complete degeneration.

These affected areas were exactly those not permeated by the contrast medium in the arteriogram.

RADNER 1951 has mentioned a case in which serious complications were attributed to intracranial interruption of the vertebral arterial system leading to insufficient blood supply to the brain stem, partly caused by obstruction of the artery by the catheter and partly by increased concentration of the contrast medium. This view is supported by SJÖGREN 1953 and LINDGREN 1954.

Irrespective of the method of vertebral angiography employed, however, serious complications have been described by SUGAR, HOLDEN and POWELL 1949, LINDGREN 1950, RADNER 1951, SUTTON and HOARE 1951, ROKANSKI 1952, KRAYENBÜHL and RICHTER 1952, SJÖGREN 1953, NAMIN 1954, SUGAR and BUCY 1954. The common feature of the autopsy findings was severe arteriosclerosis.

The author cannot but conclude that at present there exists no contrast medium wholly innocuous to the vascular wall.

The cause of death in this patient was coronary thrombosis; this, however, constitutes another problem.

SUMMARY

Clinical and experimental experiences with the various contrast media used in cerebral angiography are described and discussed. A case is reported in which the injection of Thorotrast into the vertebral artery was followed by serious complications.

ZUSAMMENFASSUNG

Klinische und experimentelle Erfahrungen mit verschiedenen, bei der cerebralen Angiographie benutzten Kontrastmitteln werden beschrieben und diskutiert. Ein Fall, bei dem die Injektion von Thorotrast in die Arteria vertebralis ernsthafte Komplikationen zur Folge hatte, wird berichtet.

RÉSUMÉ

L'auteur décrit et discute des recherches cliniques et expérimentales faites avec les différents produits de contraste utilisés en angiographie cérébrale. Il présente un cas où l'injection de Thorotrast dans l'artère vertébrale a été suivie de complications graves.

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EXPERIMENTAL COMPARISON OF DIODONUM WITH SODIUM ACETRIZOATE WITH REFERENCE TO POSSIBLE INJURIOUS EFFECTS ON THE BLOOD-BRAIN BARRIER

by

Tore Broman and *Olle Olsson*

In recent years the contrast media used for cerebral angiography have almost exclusively been of the Diodonum type. Previous investigations (BROMAN & OLLE OLSSON 1948, 1949) showed that these contrast media are capable of impairing the permeability of the blood-brain barrier, and provided an explanation for some important clinical side-effects of cerebral angiography. The investigations also revealed that the severity of the impairment of the blood-brain barrier varied from one make of contrast medium to another despite the fact that they were said to be chemically identical. Umbradil 35 % proved the least injurious. In animal experiments it was found that the application time for Umbradil could be prolonged to anything up to 40 seconds without subsequent demonstrable injury.

In 1952, WALLINGFORD et coll. described a new contrast medium, the sodium salt of 3-acetylamino-2, 4, 6-triiodobenzoic acid, with three iodine atoms in the molecule as against two in Diodonum. The preparation was first manufactured in U. S. A. by Mallincrodt Chemical Works under the name of Urokon. It was afterwards also produced in Sweden under the name of Triurol (Leo) and, later, of Reopak (Astra). This contrast medium should preferably be referred to as sodium acetrizoate. The range of use of the compound includes cerebral angiography.

Thus in 1952 SEAMAN & SCHWARZ described good results with the use of the substance for this purpose in a 30 per cent concentration. Recently ODÉN (1955) reported a thorough investigation of the value of this contrast medium for carotid angiography. From observations made in a fairly large series he concluded that Triurol causes much less discomfort to the patient than Umbradil and should therefore be preferred for angiography. We began to use Triurol 25 % for clinical examinations in 1953 at Lund and in 1954 carried out an experimental investigation to reveal any difference between the local toxic effect of the Triurol and Umbradil types of contrast media. The results are described below.

Technique

The technique is given in detail in a previous article in this journal (BROMAN & OLSSON, 1956).

Results

In our previous investigations we have shown that an application time of 10 seconds was sufficient for Umbradil 50 % to produce impairment of the blood-brain barrier. In a 35 per cent solution, Umbradil produced no demonstrable damage, not even with an application time of as much as 40 seconds. We now studied Triurol in the same way for any side-effects, but as a precautionary measure we complemented the earlier experiments with Umbradil 35 %, because we had reason to suppose that with this concentration the application time of 40 seconds represented the upper non-injurious limit. In the present investigation the injection pressure was controlled in the way described in the above-mentioned paper. The injection pressure was never allowed to exceed 200 mm Hg. The results of the experiments are summarised in the following table.

The supplementary experiments using Umbradil 35 % confirmed the assumption that an application time of 40 seconds is a limiting value. While an application time of less than 40 seconds was never followed by any demonstrable impairment of the permeability of the cerebral vessels, prolongation of the application time beyond this limit impaired the permeability of the cerebral vessels in 2 out of 4 cases. Essentially the same local toxic effect was demonstrated in experiments using Triurol in a corresponding concentration and application time. However, as Triurol, thanks to its higher iodine content, may be used in lower concentration for clinical purposes, the investigation was extended to include this medium in a 25 per cent solution. The investigation showed that with a long application time, 40 seconds or more, even this low concentration was injurious.

Table

Comparison between Sodium acetrizoate and Diodonum with respect to their effects on the cerebral vessels

No.	Solution	Dose ml	Time sec	Impairment of permeability	Cramp
1	Urokon 50 %	15	10	—	0
2	» » »	20	»	++	0
3	» » »	14	»	+	0
4	» » »	8	15	—	0
5	» » »	40	20	(+)	0
6	» » »	25	»	+	0
7	» » »	45	»	++	0
8	» » »	50	24	+	0
9	Triurol 35 %	75	40	—	0
10	» » »	80	45	(+)	0
11	» » »	42	40	++	0
12	Reopak » »	80	»	[1]—(+)	[2]++
13	» » »	»	»	++	+++
14	Umbradil 35 % ...	60	40	—	0
15	» » » ...	50	»	—	0
16	» » » ...	78	»	+	0
17	» » » ...	»	»	+	0
18	Triurol 25 %	80	40	—	0
19	» » »	75	44	?	0
20	» » »	45	40	+	++
21	» » »	75	44	+	+

[1] Punctuate blue spots due to air embolism.
[2] Air embolism.

Discussion

The investigation showed that, as far as the injurious effect on the blood-brain barrier is concerned, Triurol did not differ essentially from Umbradil. This also applies to Triurol in such a low concentration as 25 per cent, which is the lowest possible for clinical angiography. Thus, not even in low concentration is this contrast medium free of risks; consequently, as hitherto, the hazards involved by the contrast medium must be taken into full account in every individual case before deciding upon cerebral angiography. It is true that in clinical angiography the application time is much shorter than that found to be injurious in animal experiments, but on the other hand the possibility of the toxic effect being enhanced by other factors must be borne in mind (Broman, Forssman & Olle Olsson 1950). The reaction that might be expected consists mainly of a feeling of discomfort. This symptom, as shown by Odén (1955), may be explained in part by the osmotic pressure of the contrast medium. But, as we demonstrated in 1948, it is not mainly the osmotic pressure but the toxicity of the contrast medium that is

responsible for the actual injury to the cerebral vessels. The advantage offered by Triurol therefore is that in low concentration with a correspondingly low osmotic pressure it causes less symptoms to the patient.

As to the convulsions observed in association with injury to the cerebral vessels two possible explanations suggest themselves: the disturbance of the vascular permeability is caused by the toxic effect of the contrast medium, the vascular lesion leading to a secondary irritation of the nerve cells, or the nerve cells in the brain may be irritated directly by the contrast medium. If the latter possibility be accepted, the vascular lesion could be mainly secondary to the epileptic convulsions, possibly in combination with, or only enhanced by, the toxic substance injected. The fact that cerebrovascular injury was always demonstrable in the animals in which convulsions had been observed, while cerebrovascular injury did not always result in convulsions, argues for the convulsions being secondary to cerebrovascular injury. Another argument supporting this line of thought is that the cerebrovascular disturbance was limited to that half of the brain that had received the injection.

It is remarkable that convulsions occurred only in those experiments in which long injection times were used. This suggests that cerebral anoxia in association with a prolonged injection time might be a contributory factor in the development of convulsions.

In review, it may be concluded that, as far as the local toxic effect on the brain is concerned, Triurol 25 % has the same low toxicity as Umbradil 35 %, but both are superior, for example, to Diodrast 35 %. An advantage of Triurol over Umbradil consists in its causing less discomfort to the patient because of the lower osmotic pressures produced.

SUMMARY

An experimental investigation of sodium acetrizoate in the form of Triurol 25 % showed that it disturbed the blood-brain barrier to the same extent as Diodonum in the form of Umbradil 35 %.

ZUSAMMENFASSUNG

Eine experimentelle Untersuchung mit »sodium acetrizoate» in der Form von Triurol in 25 %iger Lösung zeigte, dass es die Bluthirnbarriäre in dem gleichen Ausmasse wie Diodon in der Form von 35 %igem Umbradil zerstört.

RÉSUMÉ

Une étude expérimentale de l'acétrizoate de sodium sous forme de Triurol à 25 % a montré qu'il perturbe la barrière sang-cerveau au même degré que la Diodone sous forme d'Umbradil à 35 %.

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AUS DER RÖNTGENABTEILUNG (LEITER: PRIV. DOZ. DR. K. DECKER) DER NERVENKLINIK (DIREKTOR: PROF. DR. K. KOLLE) DER UNIVERSITÄT MÜNCHEN, DEUTSCHLAND

DER SPASMUS DER A. CAROTIS INTERNA

von

K. Decker

Der Begriff des Spasmus der cerebralen Gefässe wird häufig gebraucht. Klinische Neurologen erklären auf diese Weise rasch vorübergehende cerebrale Ausfallserscheinungen. Neuroanatomen führen darauf bestimmte histologische Veränderungen zurück.

Der Bau der Gefässwand lässt eine Kontraktion möglich erscheinen; die Innervation auch der cerebralen Gefässabschnitte ist gesichert. Sogar Ganglienzellen wurden in der Adventitia der Carotis beschrieben. Experimentelle Untersuchungen über den Ablauf des Krampfes der intracraniellen Gefässe sind selten. BROWNE und STERN zeigten bei angiographischen Untersuchungen von Katzen einen bemerkenswerten Unterschied im Verhalten der intracraniellen- und extracraniellen Zirkulation. Sie untersuchten den Einfluss von Gefässreizen, Eingriffen am cervikalen Sympathicus und der intraarteriellen Injektion von Luft. Fast ausschliesslich fanden sie Kontraktionen nur am extracraniellen Gefässsystem. Ähnlich zeigen experimentelle Beobachtungen während der Angiographie mit Jodpräparaten bei direkter Beobachtung der pialen Gefässe keine Verengerung, sondern eher Vasodilatation (BLOOR und Mitarbeiter). Im Gegensatz zu den Beobachtungen am Herzen ist der Ablauf der normalen Pulswelle in der Carotis und intracraniell überhaupt nicht studiert.

Die vorliegende Arbeit befasst sich ausschliesslich mit den Veränderungen am Halsteil der A. carotis während der Kontrastmittelinjektion, da Verschiedenheiten im extra- und intracraniellen Verhalten bestehen können. Bei der angiographischen Untersuchung wird grundsätzlich versucht, möglichst die Nadelspitze im Röntgenbild zu erfassen. Eine Reihe von Beobachtungen konnten im Verlauf der letzten Jahre gemacht werden. Liegt die Injektionsnadel frei im Gefäss, ist am Verlauf

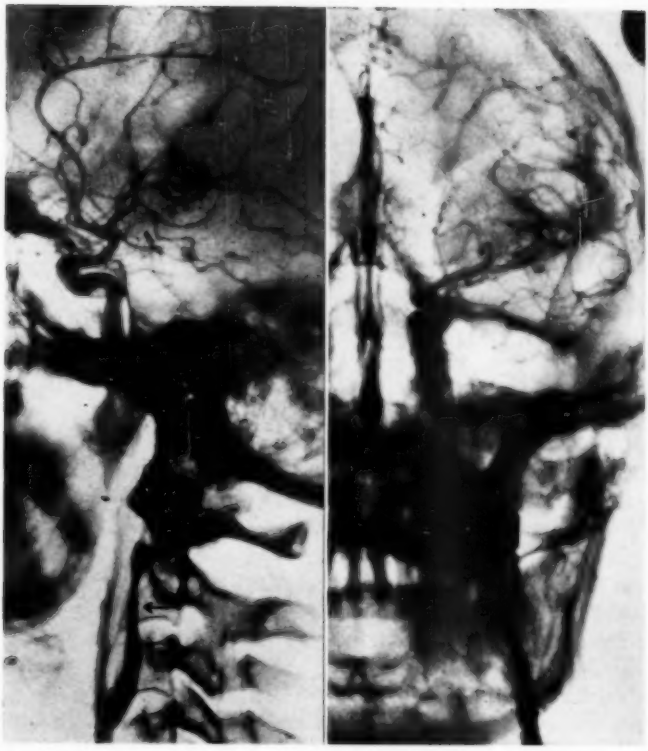
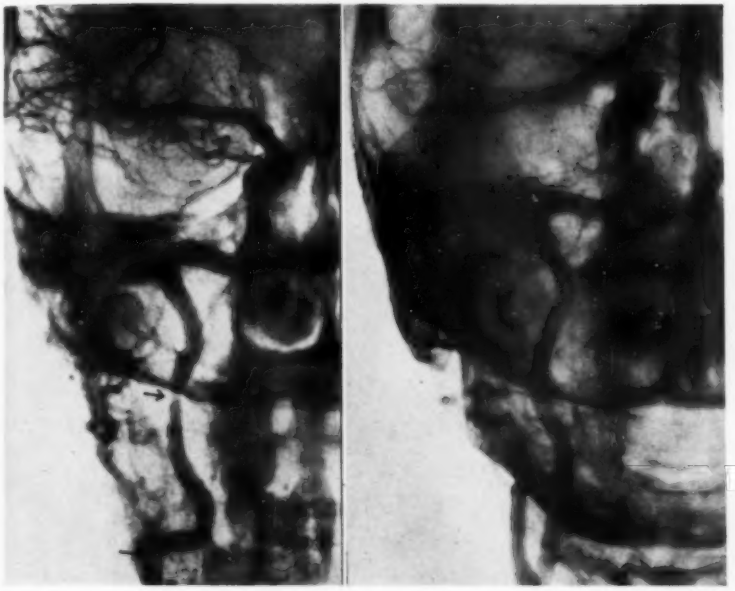


Abb. 1. Am Halsteil der Carotis interna sind in beiden Projektionsrichtungen Einengungsringe zu erkennen, die von weiteren Gefässtrecken wieder abgelöst werden. Die Nadel liegt frei im Gefäss. (32-jähr. Kranke mit seltenen epileptischen Anfällen.)

der Konturen der A. carotis nichts Besonderes zu erkennen. Gelegentlich sieht man aber auch in diesen Fällen einzelne kleine Einschnürungen des Gefässlumens. Diese können unmittelbar an der Einstichstelle der Nadel liegen oder auch noch weiter der Schädelbasis zu (Abb. 1). Die Ursache dieser Gefässkontraktion ist unklar. Es kann eine gesteigerte Bereitschaft zur Arterienkontraktion vorliegen, da auffällig viele Patienten mit Krampfanfällen dieses Phänomen zeigten. Man könnte auch an eine starke Druckwirkung während der Injektion als Ursache denken oder an die Anwendung von zu kalter oder überwärmter Lösungen (Ziedses des Plantes). Dass das Röntgenbild tatsächlich einer vorübergehenden Veränderung der Gefässwand entspricht, kann nur die Wiederholung der Untersuchung sicher erkennen lassen. Es muss sich später



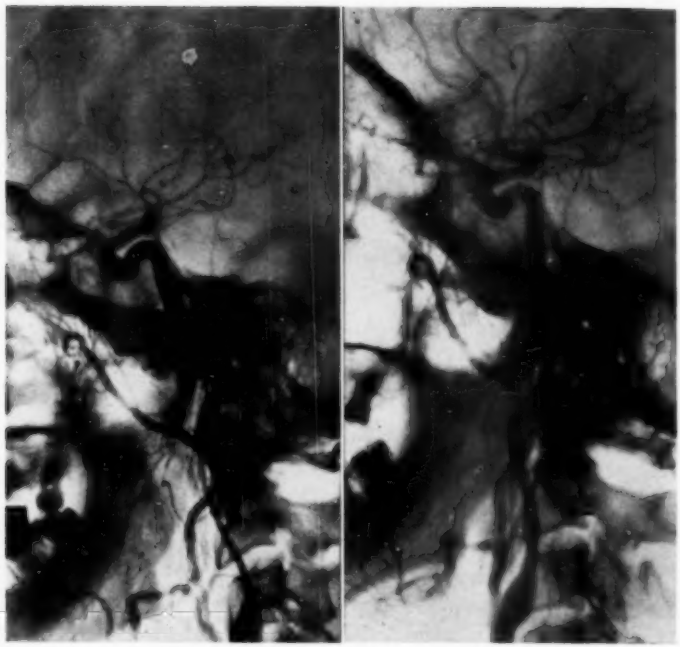
a b

Abb. 2. a) Zuerst geringfügige paraarterielle Injektion. Bei der zweiten Injektion einzelne Einengungen des Gefässlumens am Halsteil (Pfeile). b) Etwa 20 Minuten später Kontrastmittelinjektion nach erneuter Punktion des Gefässes. Das Lumen der Carotis interna ist nun ohne Einengung. (47-jähr. Mann mit cerebralen Gefässstörungen.)

ein normal weites Gefässlumen darstellen (Abb. 2). Auch die Eigenart der Verengerung am Gefäss lässt schon den Verdacht eines Krampfzustandes aufkommen.

Die Unterscheidung gegenüber organischen Wandveränderungen, sklerotischen Einlagerungen oder endangiitischen Einengungen ist aber sicher nicht leicht. Vor allem ist die richtige Beurteilung schwer, wenn das Gefässlumen der Halsschlagader allgemein verengt ist. Die drei Beispiele der Abb. 3 bis 5 zeigen fast gleichartige Befunde im Röntgenbild. Ihre Genese ist aber verschieden.

Im ersten Falle (Abb. 3) hatte eine geringfügige paraarterielle Injektion eine starke Verengerung der Carotis erzeugt ohne dass während und nach der Angiographie der Kranke besondere Störungen zeigte. Die nächste Einengung (Abb. 4) ist die Folge einer ausgedehnten Injektion des Kontrastmittels unter die Gefässinnenhaut, die ausser stärkeren Schmerzen an der Punktionsstelle ebenfalls störungsfrei vertragen wurde. Und die letzte Beobachtung (Abb. 5) ist wahrscheinlich auf organische

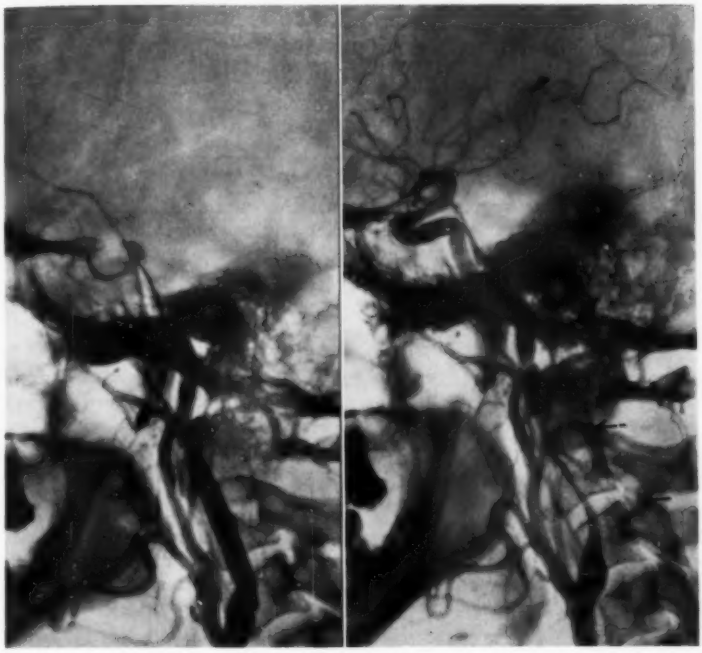


a b

Abb. 3. a) Nach vorhergehender Carotispunktion die Arterie am Halse erheblich eingeengt mit einzelnen Unregelmässigkeiten der Wandkontur. Wenig Kontrastmittel in die intracraniellen Gefässe. b) Erneute Untersuchung eine Woche später. Eine durchschnittlich weite Gefässlichtung ohne Veränderung zwischen den einzelnen Aufnahmen der Bildserie; 6 Bilder pro Sekunde. (40-jähr. Patient mit epileptischen Anfällen, teilweise vom fokalen Typ.)

Gefässwandveränderungen zurückzuführen. Neben cerebralen und peripheren Durchblutungsstörungen zeigte eine Wiederholung der Angiographie das gleiche Bild des verengten Gefässlumens ohne dass sich eine Besonderheit an der Nadellage nachweisen liess.

Aber auch bei weiteren Krankheitszuständen lassen sich Verengerungen der Carotis am Halse beobachten. Wir hatten Gelegenheit, einen Fall einer Verlegung der A. car. communis am Abgang aus der Aorta zu beobachten, wobei der Durchmesser der weiter cerebralwärts gelegenen Gefässe am Halse stark reduziert war. Auch anlagemässige Differenzen des Gefässlumens zwischen beiden Seiten müssen bedacht werden. In einem Falle konnte die Differenz der intracraniellen Carotiden auch autoptisch noch belegt werden. Die Grunderkrankung war eine Epilepsie



a b

Abb. 4. a) Während der Angiographie wurde ein Teil des Kontrastmittels in die Gefässwand injiziert. b) Carotis wird einige Minuten später weiter distal am Halse punktiert und das Kontrastmittel ohne Schwierigkeit injiziert. An der Stelle der ehemaligen paraarteriellen Injektion eine erhebliche Einengung des Gefässes (Pfeile). (32-jähr. Patient mit Anfällen vom Jackson-Typ, möglicherweise nach Schädelunfall.)

Abb. 5

Abb. 5. Bei mehrfacher Kontrastmittelinjektion immer gleiches Bild. Carotis interna nach ihrem Abgang am Ende des Sinus caroticus bis zum Carotissiphon stark verengt. (45-jähr. Mann mit allgemeiner Gefässerkrankung. Mehrfache Insulte, Durchblutungsstörungen an den Beinen.)

und die Patientin verstarb Monate nach der Angiographie im Status epilepticus. Liegen sehr tiefe Teilungen der A. carotis etwa in Höhe des 6. oder 7. Halswirbelkörpers vor, dann scheint häufiger die Carotis interna aussergewöhnlich schmal zu sein.

ZUSAMMENFASSUNG

Die Bedeutung einer engen Carotis am Halse wurde zu klären versucht. Dieser Befund im Carotisangiogramm kann durch Wandveränderungen bei organischen Gefässerkrankungen, aber auch durch eine Reihe anderer Ursachen, vorallem durch inkorrekte Kontrastmittelinjektion, bedingt sein.

SUMMARY

An attempt was made to clarify the significance of a narrowing of the carotid artery in the neck. This finding may indicate organic changes in the walls of the vessels but may also arise from various other causes, such as incorrect injection of the contrast medium.

RÉSUMÉ

L'auteur s'est efforcé d'élucider la signification d'un rétrécissement de l'artère carotide dans le cou. Ce signe peut indiquer des modifications organiques dans les parois du vaisseau, mais peut aussi provenir de diverses autres causes, telles qu'une injection incorrecte du moyen de contraste.

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Ziedses des Plantes: Persönliche Mitteilung.

SERVICES DE NEURO-RADIOLOGIE (MÉDECIN-CHEF: DR. LANGS) ET DE NEURO-CHIRURGIE (MÉDECIN CHEF: DR. WORINGER) DE L'HÔPITAL PASTEUR DE COLMAR, (HAUT-RHIN), FRANCE

ÉTUDE SÉRIO-ANGIOGRAPHIQUE DE LA DYNAMIQUE CIRCULATOIRE DU CERVEAU

par

E. Woringer, A. Langs, J. P. Braun et *J. Baumgartner*

L'étude de la morphologie du réseau vasculaire cérébral après injection d'un produit de contraste dans la carotide ainsi que celle de ses variations dans les cas pathologiques paraît avoir été épuisée à l'heure actuelle, au moins en ce qui concerne ses grandes lignes. De nouvelles acquisitions d'ordre morphologique semblent ne plus pouvoir être gagnées que par l'étude de détails menus et surtout circonscrits. Un nouveau chapitre plein de promesses traitant la dynamique de la circulation est maintenant ouvert.

Le présent travail basé sur une documentation de 152 sério-angiographies par voie carotidienne pratiquées chez le normal et le pathologique, est voué à la recherche des renseignements que peut nous donner l'évaluation de la dynamique circulatoire cérébrale, et en particulier, de préciser la vitesse de la circulation du sang à travers l'encéphale et d'en apprécier les variations sous l'influence de différents facteurs tels que tension artérielle, type de l'anesthésie choisie, oedème cérébral, états pathologiques du cerveau. Il nous a permis de découvrir certaines caractéristiques dynamiques régionales saisissables sur le phlébogramme, dont la connaissance fait faire un pas en avant au diagnostic d'altérations cérébrales localisées.

Seul le problème de la vitesse de la circulation sera traité ici. Nous nous sommes délibérément détournés de celui du débit.

Technique

L'angiographie est pratiquée sous anesthésie générale induite au pentothal, complétée et entretenue au protoxyde d'azote et au trilène en circuit semi-ouvert. La ponction de la carotide primitive, parfois de la carotide interne, est faite à l'aide d'une aiguille munie de son mandrin. L'injection de 8 cc de produit de contraste (Diodone à 35 %) se fait en deux secondes. La prise des clichés est effectuée par le sériographe de Schönander, généralement à raison d'un cliché par seconde avec un minimum de 10 clichés par série; ceci permet d'encadrer toute la révolution circulatoire cérébrale si l'on procède de façon à n'avoir aucune trace de contraste à l'intérieur de la boîte cranienne ni sur les premiers, ni sur les derniers clichés de la série. Le sériographe A. O. T. Schönander permet d'étudier un circuit vasculaire d'une durée totale de 15 secondes. Sa cassette peut contenir 30 clichés que l'on peut faire défiler à une cadence de 2, 4 ou 6 clichés par seconde. Ceci permet une analyse détaillée de l'une ou de l'autre phase de l'angiogramme, suivant le programme établi, sans perdre le bénéfice de la notion chronologique exacte des clichés.

Méthode d'étude

Nous avons surtout analysé la durée du temps de passage du produit de contraste injecté:

1) à travers le cerveau dans son ensemble;
2) à travers la région cérébrale considérée comme pathologique du point de vue clinique, électroencéphalographique et artériographique; et
3) à travers les processus expansifs lorsque ceux-ci étaient présents et visualisés.

Nous avons ensuite confronté dans chacun de ces cas la durée des phases artérielle, capillaire et veineuse du cerveau dans son ensemble avec celle de la région pathologique. Nous avons enfin recherché l'apparition plus ou moins précoce de l'une ou de l'autre phase de l'angiogramme en rapport avec la localisation et la nature du processus pathologique. Nous avons convenu d'appeler 'phase artérielle' la visualisation d'une partie ou de tout le système artériel à partir du siphon carotidien jusqu'aux branches terminales des artères cérébrales. Nous avons appelé 'temps veineux' la durée comprise entre la première apparition du produit de contraste dans une ou plusieurs veines cérébrales et sa disparition de tout le système veineux à l'exclusion des sinus. Nous avons dénommé 'phase capillaire' la phase intermédiare située entre les deux précédentes et pendant laquelle aucune opacification artérielle ou veineuse n'a été visible. La définition du temps capillaire est souvent difficile parce que le nettoyage complet du cerveau de toute trace visible de contraste dans les vaisseaux est rarement complètement réalisé. L'évaluation en secondes du temps capillaire présente par conséquent une part d'arbitraire, qui n'influe cependant évidemment pas sur la durée totale de perfusion à travers tout le cerveau.

Cas normaux. Rarement un angiogramme a été pratiqué chez un individu absolument normal; certains de nos malades ont cependant pu être considérés comme des cas normaux du fait qu'ils n'ont présenté qu'une symptomatologie discrète et douteuse parlant en faveur d'un processus pathologique cérébral. D'autre part, quelques uns de nos malades chez lesquels un angiogramme a été pratiqué avant et après l'institution d'une thérapeutique, ont vu leur temps de circulation cérébrale revenir, avec leur guérison clinique, à une durée que nous avons à ce moment admise comme normale.

Cas pathologiques. Il s'agit de ceux admis au service de Neuro-Chirurgie pour des affections cérébrales de nature diverse (tumeurs, oedèmes cérébraux, troubles vasculaires, crises convulsives, etc.).

Animaux. Notre expérimentation a porté sur des chiens chez lesquels nous avons pratiqué des angiogrammes sous anesthésie générale, sous hypotension contrôlée et après avoir provoqué de l'oedème cérébral.

Résultats

Vitesse circulatoire cérébrale normale

Chez l'homme normal le temps de passage cérébral du contraste varie entre 7 et 10 secondes. La phase artérielle dure 2 à 3 secondes, la phase capillaire 1 à 2 secondes et le temps veineux 3 à 6 secondes. Dans la majorité des cas la vitesse de passage telle que nous l'avons définie gravite autour de 10 secondes. Ce temps presque identique à celui trouvé par Wickbom et Schurr (6 à 10 secondes) est cependant supérieur à celui décrit par Tönnis et Schiefer (5 à 6 secondes), et par Sanchez-Perez (4 à 5 secondes).

Pour expliquer ces divergences nous avons pratiqué l'angiographie sous différentes conditions, tantôt sous anesthésie locale, tantôt en ne ponctionnant que la carotide interne, et en faisant varier les doses et la concentration du contraste (6 à 10 cc et 35 à 45 %). Les variations n'ont oscillé que dans les limites que nous avions considérées comme normales.

La vitesse de circulation n'a pas non plus varié au delà des limites normales pour des examens angiographiques itératifs, à intervalles brefs de l'ordre de 5 à 15 minutes, ou plus longs allant jusqu'à plusieurs jours.

En pratiquant des angiographies bilatérales chez le même individu la vitesse de circulation d'un hémisphère par rapport à l'autre n'a pas toujours été identique, même lorsque les deux hémisphères ont été considérés comme normaux. Il n'est pas possible, avec les documents dont nous disposons, de serrer de plus près les raisons de ces divergences.

Variations de la vitesse circulatoire cérébrale

La marge des variations de la vitesse circulatoire cérébrale normale est tellement large que les variations dans les états pathologiques vont en paraître peu importantes dans chaque cas particulier. La réalité de l'anomalie se confirme surtout par l'étude en série.

Tumeurs cérébrales. Nous ne nous étendrons pas dans ce chapitre sur la visualisation des tumeurs dont l'étude a été poussée très loin et avec précision par TÖNNIS et ses collaborateurs. Nous avons cependant relevé des exceptions concernant le cycle d'opacification des diverses tumeurs. Nous ne citons à ce propos qu'un cas de nos méningiomes qui n'a été injecté qu'au temps artériel et dont le diagnostic différentiel avec le gliome n'a pu être posé de ce fait avec certitude qu'au moment de l'intervention. Quelques autres méningiomes n'ont pas été injectés du tout.

En général le temps de circulation a dépassé, en cas de tumeur cérébrale, de 1 à 3 secondes les limites normales (voir Tableau). Ce ralentissement circulatoire a été particulièrement frappant dans nos cas de gliomes et a porté sur les phases veineuses. En dehors des cas où la tumeur cérébrale s'injecte elle-même par le contraste et clarifie par conséquent immédiatement la question de sa situation topographique, il y a tout un lot de tumeurs qui ne manifestent leur présence ni par un déplacement vasculaire suffisant pour faire un diagnostic topographique précis, ni par une opacification de leur parenchyme propre. Dans la grande majorité des cas nous avons pu faire au moins une des deux constatations suivantes.

1) Il peut y avoir opacification très précoce, même au stade artériel, d'une veine de drainage partant de la tumeur elle-même.

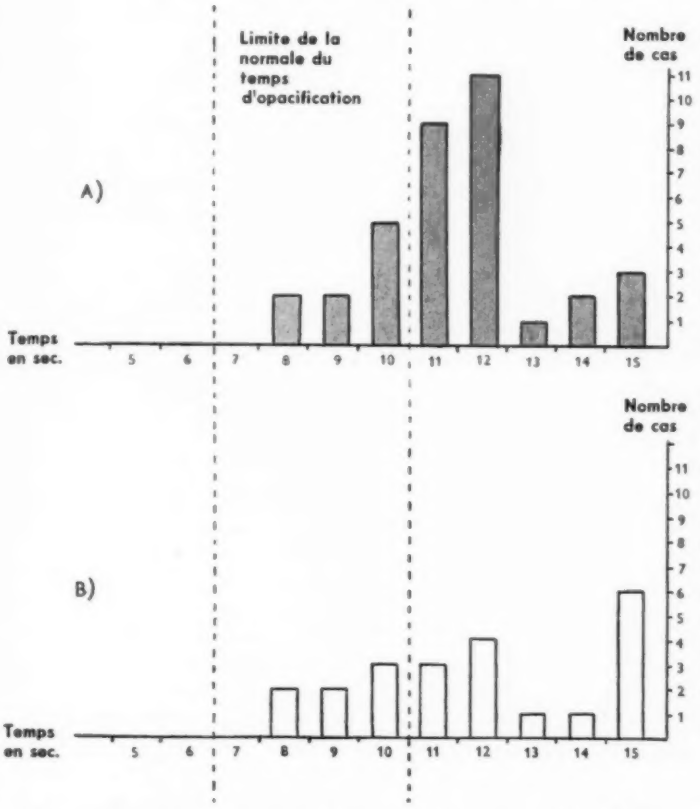
2) Dans la phase phlébographique il peut y avoir opacification prévalente d'une région cérébrale se trouvant au voisinage de la tumeur; il peut s'agir d'une opacification précoce du système veineux interne par rapport au système veineux de la corticalité, ou vice-versa, et dans ce dernier cas il peut y avoir des régions corticales à injections veineuses plus précoces que d'autres. Ce phénomène nous a particulièrement frappé dans certaines tumeurs temporales qui déterminent une opacification précoce de la veine basilaire de Rosenthal.

Ces particularités de la dynamique locorégionale du phlébogramme sont un appoint sérieux au diagnostic de tumeurs qui n'ont pas fait leur preuve par les signes morpho-angiographiques ordinaires.

Troubles circulatoires cérébraux. Il est frappant de constater combien les lésions cérébrales d'ordre vasculaire sont peu saisissables par l'image morphologique des vaisseaux telle qu'elle nous apparaît sur l'angiogramme, lorsqu'il ne s'agit pas précisément d'une thrombose d'un vaisseau, d'un anévrysme ou d'une poche d'hématome. Il est courant de ne constater aucune modification angiographique dans des cas de lésions cir-

Tableau

Temps d'opacification du système vasculaire cérébral



A) Cas de tumeurs. (Tumeurs vasculaires exclues.) La presque totalité de gliomes figurent dans les colonnes de 11 et 12 secondes.
B) Troubles circulatoires. Dans la colonne de 15 secondes quelques cas, dont la durée d'opacification a dépassé ce temps, ont été intégrés.

culatoires consécutives à un ictus et ayant déterminé des hémiplégies totales. Faute de place, il nous est impossible de faire état individuellement comme ils le mériteraient, de tous nos cas faisant partie du groupe des troubles circulatoires cérébraux. Retenons simplement que:

a) Dans la majorité des cas de notre série il y a eu ralentissement de la circulation souvent jusqu'à 15 secondes et quelquefois au-delà. Nous avons constaté également un ralentissement de la circulation dans l'hémisphère atteint en comparison avec celle de l'hémisphère sain.

b) Il y a eu accélération de la vitesse de circulation, autant absolue que relative, surtout dans un de deux cas après sympathectomie péricarotidienne et ablation du ganglion cervical supérieur. Ces cas méritent d'être cités quoiqu'une plus longue série demande à confirmer leur valeur.

Influence de l'hypotension contrôlée. Les circonstances ne nous ont permis de faire une observation valable de l'incidence de l'hypotension contrôlée sur la vitesse circulatoire cérébrale qu'une seule fois chez l'homme. En revanche nous avons poussé cette étude de façon plus précise chez l'animal.

Nous avons pu constater que la vitesse de circulation est diminuée par l'hypotension artérielle induite par l'Arfonad; mais sans que l'appréciation en chiffres ait une précision d'ordre mathématique, on peut tout de même dire que la diminution de la vitesse circulatoire n'est nullement proportionelle à la chute de tension. Ce n'est que pour des chutes de tension très importantes telle que celle observée chez un de nos chiens, où elle a été de 12 à 2 cm Hg, que le temps de circulation a augmenté de 5 à 9 secondes.

Influence de l'oedème cérébral. Dans tous les cas où la notion d'oedème cérébral a pu être confirmée chez l'homme, cliniquement ou à l'intervention, la vitesse de circulation cérébrale a été ralentie.

Nous basant sur la notion de l'apparition d'oedème cérébral accompagné de l'augmentation de la tension veineuse en cas d'hypercapnie, nous avons observé des variations de la vitesse circulatoire transcérébrale chez le chien lors de l'élévation de la tension veineuse mesurée dans la jugulaire interne, lorsque l'animal respirait en circuit clos sans chaux sodée. Nous avons pu constater dans ces cas une diminution de la vitesse de la circulation du sang à travers l'encéphale. (Chez le chien nous avons dû nous borner dans la majorité des cas à l'appréciation de la vitesse de circulation d'après l'artériogramme, les veines de l'encéphale du chien ne s'opacifiant pratiquement pas avec l'emploi d'une solution de contraste à 35 %.)

RÉSUMÉ

Sur le cerveau normal et pathologique de l'homme, et sur celui du chien, 152 sérioangiographies ont été faites à l'aide d'un sério-angiographe A. O. T.-Schönander. Le temps de circulation mesuré à partir du franchissement du siphon carotidien par le produit de contraste jusqu'à la fin de sa pénétration dans les sinus est, chez l'homme normal, de 7 à 10 secondes. Le temps du passage du contraste à travers le cerveau est augmenté d'une façon générale dans les cas d'oedème cérébral, de troubles circulatoires et de tumeurs

cérébrales visibles ou non à l'angiogramme. L'hypotension artérielle détermine une diminution modérée de la vitesse de circulation cérébrale. Dans la phase phlébographique il peut y avoir une opacification prévalente d'une région cérébrale se trouvant au voisinage de la tumeur.

SUMMARY

One hundred and fifty-two serial angiographies were carried out on normal and pathologic brains in human subjects as well as in dog, employing the Schönander A. O. T. apparatus. The circulation time was measured from the moment the contrast medium reached the carotid syphon until it had finally entered the sinuses, and in normal human subjects was found to be from 7 to 10 seconds. It was found to be generally increased in cases of cerebral oedema, circulatory disturbances, and in cerebral tumours whether visualized or not in the angiogram. Arterial hypotension caused a moderate increase in the speed of the circulation. In the venous phase, a higher contrast density may be observed in the region of the brain near the tumour.

ZUSAMMENFASSUNG

Mit Hilfe des Serienangiographen A. O. T. der Firma Schönander wurden 152 Untersuchungen an menschlichen gesunden und pathologischen Gehirnen sowie an Hundegehirnen ausgeführt. Die Zirkulationszeit vom Augenblick des Eintrittes des Kontrastes in den Carotidensiphon bis zu dessen völliger Penetration in die Sinus beträgt beim Menschen in Normalfällen 7—10 Sekunden. Die Kontrastpassage durch das Gehirn ist in Fällen mit Hirnödem, Zirkulationsstörungen und mit auf Angiogrammen sichtbaren oder unsichtbaren Hirntumoren generell beschleunigt. Die arterielle Hypotonie veranlasst eine mässige Herabsetzung der cerebralen Zirkulationsgeschwindigkeit. In der venösen Phase kann man eine erhöhte Kontrastdichte eines in der Gegend des Tumors liegenden Hirngebietes beobachten.

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ARTERIES OF THE BRAIN

An anatomic study

by

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A concept of a uniform pattern of arteries throughout the brain has been derived from a six-year study of the blood vessels of slightly over 500 brains. A review of this material has also emphasized the accuracy of the observations made by others (1, 3) suggesting a constant relationship of the cerebral arteries to specific vesicles of the neural tube.

Previous contributions concerning the anatomy of the blood vessels of the brain have, for the most part, been reports of the results of gross dissection, of injection of staining material, and of microscopic study of the capillaries. The injection of dye have, by discoloration of brain tissue, demonstrated the extent of arterial supply, but the presence of anastomoses makes the results with this method of doubtful value. There remains a gap in our understanding of the precapillary network of arteries within the brain. This deficit in our knowledge of the total vascular pattern has been overcome by studying roentgen films taken after injection of radiopaque substances into the cerebral vessels of fresh brains of cadavers. This method is an application of a time-honored procedure which has been exhaustively pursued by us in the studies of the arteries of the brain.

Materials and method. Uninjured and untreated brains removed from fresh cadavers on the day of injection are best. Specimens treated with preserving solution are not satisfactory. For study of the small vessels, brains taken from cadavers between the ages of 15 and 35 years are desirable. The materials employed as injection masses have varied depending on the size of blood vessels to be studied. A vinylite-acetone solution, which solidifies in the vessels at room temperature, is employed as a vehicle for the radiopaque material. Five grams of Vinylite (VYHH-

Bakelite Co., U. S. A.), a white plastic powder, is dissolved in 30 cubic centimetres of acetone to form a clear solution. Various lead substances may then be added to this vehicle. Four grams of red lead powder (painter's red lead) in 30 cubic centimetres of the vinylite-acetone solution results in the most successful demonstration of the larger vessels (2). For demonstration of the smaller vessels, equal parts of a liquid lead compound (Lead 2-ethylhexoate, National Lead Company, U. S. A.) and the vinylite-acetone solution is used. The liquid lead compound is a viscous material but may be thinned by heating in a closed container in a water bath for about thirty minutes before being added to the vinylite-acetone solution. On agitation of the mixture, a supernatant, resin-like substance develops which when removed leaves a fluid sufficiently thin to flow freely through relatively small vessels, when injected under slight pressure.

Following injection of single or multiple blood vessels, roentgenograms (Kodak Type M industrial X-ray film) are taken. Stereoviews of whole specimens and plain films of serial slices of brains, with nuclear masses outlined by surface application of barium sulphate, has made possible visualization of the course, ramification and distribution of vessels in an undistorted relationship to surrounding structures.

Discussion

Following organization of the accumulated data into an integral whole, it became evident that all segments of the encephalon have analogous arterial patterns. From two main sources, the rostral or internal carotid arteries, and the caudal or vertebral-basilar arteries, vessels arise which give off perforating branches to the deep cell masses and then course over the surface to irrigate the dorsal or suprasegmental regions. This simple design of perforating and surface arteries is found throughout the brain and persists despite the complex developmental readjustment of the components of the encephalon (Fig. 1).

On dividing the brain into its five primary segments, namely: telencephalon, diencephalon, mesencephalon, metencephalon, and myelencephalon, and then studying the vasculature of each, it became evident that the arteries of the brain have a constant relationship to vesicles of the neural tube. The direction and position of the arteries are governed by the anatomic location of the cellular masses. The anterior cerebral artery, the terminal portion of the internal carotid artery, supplies the rostral portion of the telencephalon. The perforating branches of the anterior cerebral artery irrigates the antero-mesial portion of the corpus striatum or deep cell mass and the surface branches the antero-mesial aspect of the cortex. The next major branch of the internal carotid

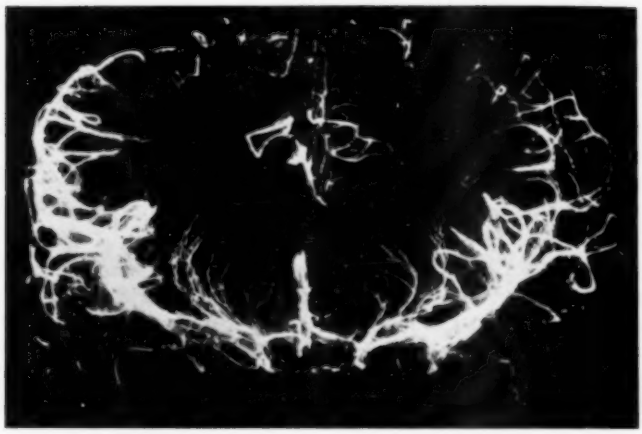

Fig. 1. Cross section of forebrain showing the pattern of perforating and surface vessels of the anterior and middle cerebral arteries.

artery, the middle cerebral artery, irrigates the supero-lateral portion of the corpus striatum and a comparable area of the cerebral cortex. The anterior and middle cerebral arteries supply only telencephalic structures. This remarkable limitation is exemplified especially in the distribution of the perforating branches. Those arising from the anterior cerebral artery supply structures rostral to the chiasm and have never been found to enter the diencephalic portion of the hypothalamus (Fig. 2). Those of the middle cerebral artery ramify in the putamen and lateral two-thirds of the globus pallidus and then traverse the internal capsule to enter the caudate nucleus, but do not cross phylogenetic boundaries to enter the thalamic mass.

The remainder of the telencephalon is supplied from two large and several small branches which phylogenetically had their origin from the first portion of the intracranial division of the internal carotid artery. The anterior choroidal has remained relatively unchanged in origin during the phylogenetic development of the nervous system. Studies in comparative anatomy reveal that the posterior cerebral artery takes origin from the internal carotid artery and later in the phylogenetic scale connects with the basilar arterial system. It therefore becomes apparent that the vessel commonly referred to as the posterior communicating artery is in truth the proximal part of the posterior cerebral artery. The origin of the anterior choroidal and posterior cerebral vessels from the proximal portion of the intracranial section of the internal carotid artery indicates that their region of supply should be, in the

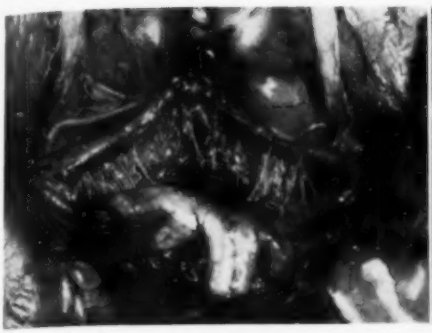

Fig. 2

Fig. 3

Fig. 2. Injected perforating branches of the proximal portions of the anterior cerebral arteries. Optic nerves and chiasm are folded posteriorly. The branches extend to region of the chiasm but not beyond.

Fig. 3. Base view of brain centered on bifurcation of basilar artery. Basilar and superior cerebellar arteries (below) and the proximal portions of the posterior cerebral arteries (posterior communicatings) at the internal carotids (above) are ligated in place. Rostral and caudal arterial systems of brain are connected by communications of the posterior cerebral and distal divisions of basilar artery (mesencephalic arteries).

main, the caudal portion of the telencephalon which adjoins the diencephalon. In fact, they supply to a large extent the archipallium of the mesial aspect of the temporal lobe; the anterior choroidal artery also supplying the mesial or phylogenetically older portion of the globus pallidus. The overlapping of supply of the anterior choroidal and posterior cerebral arteries further indicates the probable closely related development of these vessels. Both supply the mesial temporal lobe, the diencephalon, and the choroid plexus and both have at least four prominent areas of generous anastomosis on the surface of the brain, namely the mesial aspect of the temporal lobe, in the region of the hypothalamus, on the geniculate body, and within the choroid plexus.

The diencephalon receives its blood supply exclusively from branches which have their origin phylogenetically from the proximal portion of the intracranial division of the internal carotid artery. Several small branches enter the hypothalamus directly from the internal carotid artery but the greatest portion of this vesicle is supplied from the anterior choroidal-posterior cerebral artery complex. Therefore, it may be stated that the entire arterial system of the forebrain is made up of branches that have their origin phylogenetically from the internal carotid arteries.

The rostral and caudal systems of blood vessels to the brain are joined through a connection of the posterior cerebral and the final division

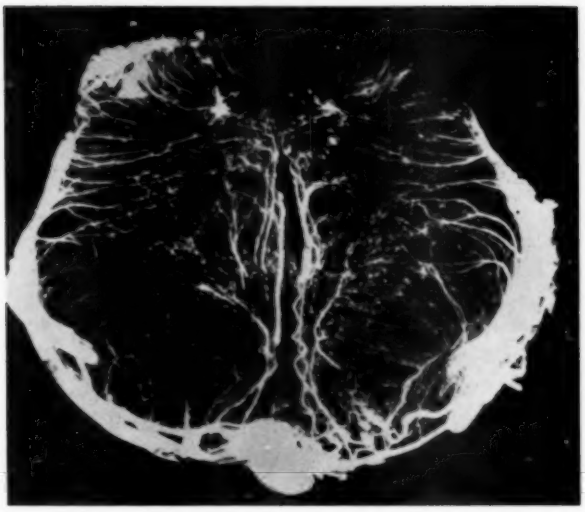

Fig. 4. Cross section of midbrain showing perforating and surface vessels.

of the basilar artery, that is, the mesencephalic arteries. (The distal divisions of the basilar artery should be referred to as the mesencephalic arteries, rather than the posterior cerebral arteries, since perforating branches of the mesencephalic artery supply the basis and tegmentum of the midbrain and then continue around the midbrain as the tectal or quadrigeminate arteries to supply the quadrigeminate or suprasegmental portion of the mesencephalon.) Usually, the mesencephalic artery is larger than the proximal portion of the posterior cerebral artery (posterior communicating artery). In fact, a relatively large artery arising from the internal carotid, continuing as the posterior cerebral artery, and with a small connection to the rostral division of the basilar artery (mesencephalic artery) is not an infrequent finding in the human (Fig. 3).

Continuing caudally, one encounters a single compact neural unit, the mesencephalon and metencephalon, which receives its blood supply from a single arterial trunk, the basilar artery. The midbrain, the rostral segment of this neural unit, is supplied by branches of the mesencephalic arteries, or in other words, branches of the distal divisions of the basilar artery. The mesencephalic arteries, similar to the arterial pattern elsewhere in the brain, give off perforating branches to the basis and tegmentum of the midbrain and then continue on to reach the quadrigeminate bodies, the suprasegmental portion of this structure (Fig. 4).

The greater portion of the basilar artery, through a series of five to eight vessels arising from either side, supplies the metencephalon. Three

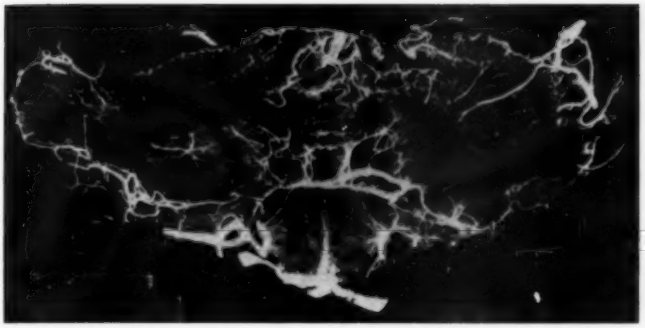

Fig. 5. Cross section of medulla and cerebellum showing perforating branches of posterior inferior cerebellar arteries to the dorso-lateral region of the medulla.

to five of these vessels, bilaterally, are destined for the pons varolii exclusively. Two to three of them, the superior cerebellar and at times the internal auditory and anterior inferior cerebellar arteries, after giving off the perforating branches, continue as lateral surface vessels to supply the cortical mantle of the cerebellum, the suprasegmental portion of the metencephalon. Here again, one finds perforating and surface vessels comparable to the arterial design at other levels.

Seemingly, change in structure of the medulla from that of the adjoining spinal cord resulted in a modification of the vascular pattern. In the spinal cord the principal cell masses are ventrally placed, whereas in the medulla they are more dorsally located. These changes necessitate an increase in the amount of blood delivered to the dorso-lateral regions of the medulla. The presence of large branches from the posterior inferior cerebellar artery to this area fulfills this need (Fig. 5). The basic pattern of perforating and surface vessels still exists at this level.

SUMMARY

A constant relationship of the cerebral arteries to specific vesicles of the neural tube exists. The basic arterial pattern is essentially the same in design, consisting primarily of central perforating and lateral surface vessels arising from a main ventral trunk.

ZUSAMMENFASSUNG

Es besteht ein konstantes Verhältnis zwischen den Hirnarterien und spezifischen Bläschen des Neuralrohres. Das grundlegende arterielle Muster ist im wesentlichen gleichartig konstruiert und besteht hauptsächlich aus Gefässen, welche von einem ventralen Hauptstamm ausgehen und zentral perforieren oder lateral an der Oberfläche verlaufen.

RÉSUMÉ

Il existe des rapports constants entre les artères cérébrales et les vésicules du tube neural. Le schéma artériel fondamental est essentiellement le même, consistant principalement en vaisseaux perforants centraux et en vaisseaux superficiels externes naissant d'un tronc principal ventral.

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FROM THE ROENTGENDIAGNOSTIC DEPARTMENT (DIRECTOR: PROF. OLLE OLSSON), UNIVERSITY HOSPITAL OF LUND, SWEDEN

ANGIOGRAPHIC DIFFERENTIATION BETWEEN ACUTE AND CHRONIC SUBDURAL AND EXTRADURAL HAEMATOMAS

by

Olof Norman

The pathophysiology of the subdural haematoma has been described in detail by GARDNER 1932 and ASK-UPMARK 1940, inter alios. According to these authors, the subdural haematoma must be regarded as a potential expansive lesion. Expansion may be due to recurrent haemorrhage, but far more important is expansion by osmosis, haemoglobin and plasma proteins being broken down in the liquefied content of the haematoma and the number of molecules and thereby the osmotic pressure increasing; the cerebrospinal fluid dialyzes through the haematoma membrane that has formed in the meantime so that the osmotic balance is restored and in consequence of this the sac progressively expands.

When the subdural haematoma has reached this stage its arteriographic appearances correspond to those characteristic of a chronic subdural haematoma as described by BULL 1940, WICKBOM 1949, and ENGESET 1950. The vessels in a limited area on the surface of the brain are lifted from the lamina interna and outline the haematoma in a regular concave curve (Fig. 1).

Although the roentgenographic appearances of the chronic subdural haematoma, which often occurs after relatively slight trauma, are well known, only few descriptions are available of the acute subdural haematoma. WICKBOM, however, makes a distinction between them and states that a subdural haematoma may also appear in an acute form as a consequence of severe trauma, generally in combination with a severe contusion and that it is usually situated more basally.

In our material at Lund, consisting of 64 cases of angiographically demonstrated subdural haematomas from 1947 to 1954, we also found,

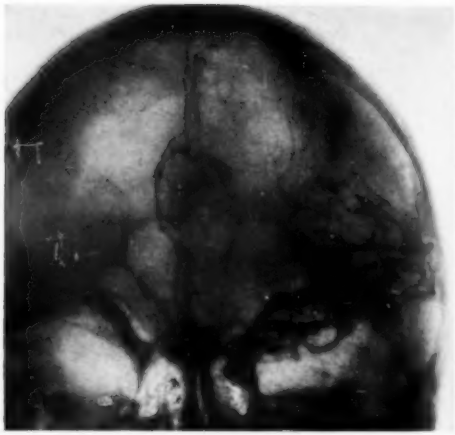


Fig. 1. Chronic subdural haematoma 5 months after trauma. Vessels in limited area on brain surface lifted from skull and outlining haematoma in a regular concavity.

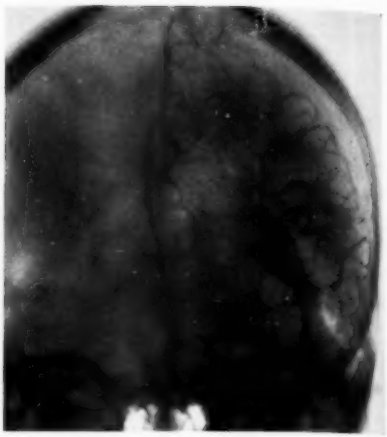


Fig. 2. Subdural haematoma 12 days after trauma. Brain in a larger area pressed away from skull. Shape of outline of brain preserved.

as might have been expected, a definite relationship between the severity of the trauma and the interval between the injury and the roentgenographic examination. This is apparent from the fact that a fracture of the skull was seen in half of our cases examined within 14 days of the trauma, but only in one out of ten examined later. A simultaneous contusion of the brain was only seen in the acute cases.

When we consider only the interval, that is, disregarding the severity of the trauma, we generally see the same roentgenographic appearances the first few days after the trauma, these (Fig. 2) differing distinctly from those of a chronic subdural haematoma. We find, usually in the a. p. view, the brain pressed away from the lamina interna, but without any changes in the shape of its outline even when the haematoma is large (Fig. 3). The roentgenogram coincides with the patho-anatomic description given by INGVAR & ASK-UPMARK 1938, of how the fresh subdural haematoma spreads fairly uniformly, with the pressure against the hemisphere distributed over a fairly large area with hardly any deformation of the profile of the brain.

In Diagram 1 the entire series of subdural haematomas is arranged according to the age of the lesion. The roentgenographic profile of the haematoma gradually changes (cf. Figs. 2, 4, and 1). During the first two weeks the appearances are one and the same, the border of the haematoma facing the cerebrum being concave and lying 'parallel' to the skull; in the

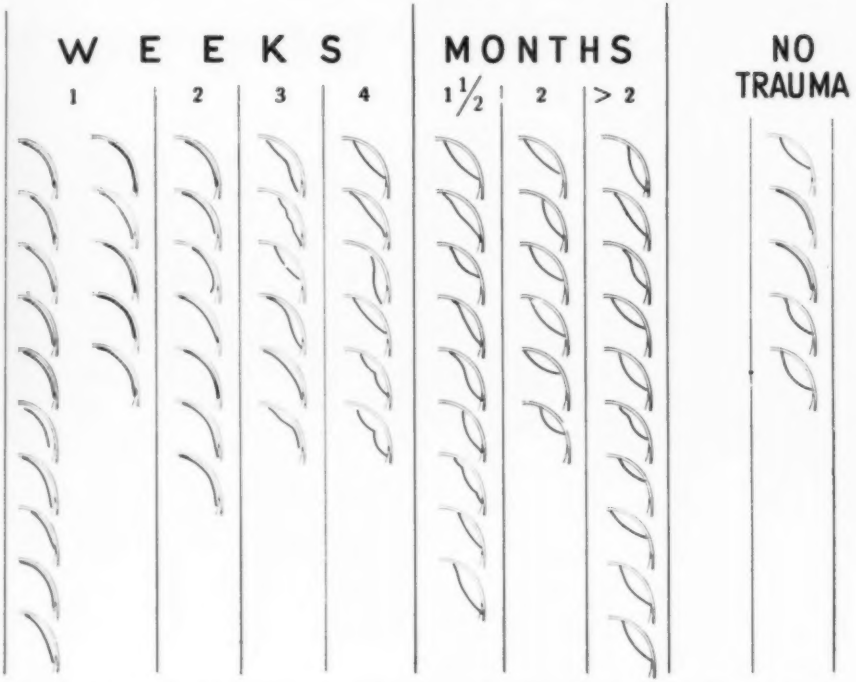
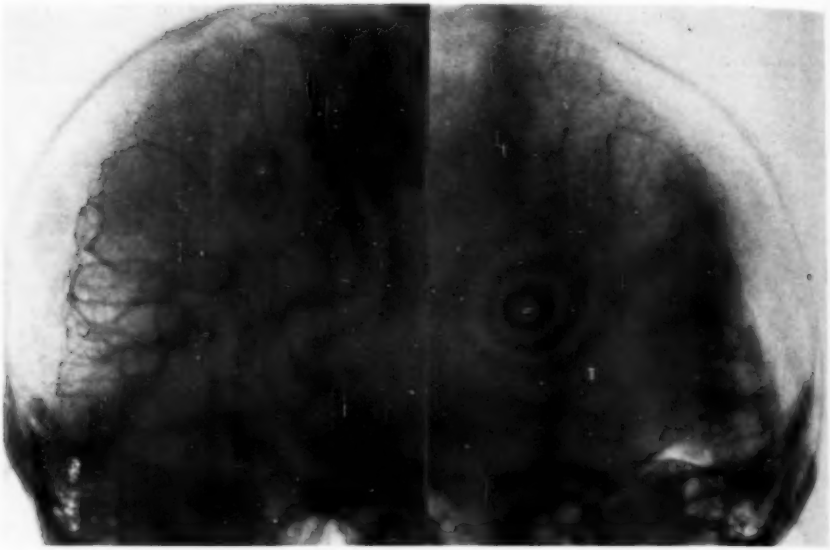


Diagram 1. Subdural haematomas arranged according to age of lesion. Extent of expansion given refers to the maximum demonstrated in each case. In order to facilitate comparison all haematomas drawn as left-sided.

third week a certain transition is discernible; but from the fourth week onwards the haematoma regularly shows signs of expansion.

It thus appears that not only the chronic, but also the acute, subdural haematoma has its own characteristic appearance. It might thus be possible, within certain limits, to assess the age of a subdural haematoma.

Diagram 2. Sketches of the 11 cases of extradural haematomas.



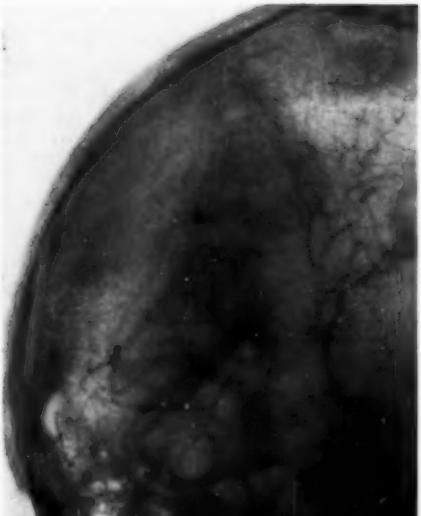


Fig. 3 (*top left*). Subdural haematoma 7 days after trauma. In spite of size of haematoma outline of the brain not deformed in early stage.

Fig. 4 (*top right*). Subdural haematoma in third week after trauma. Haematoma still fairly widespread but signs of commencing expansion.

Fig. 5 (*bottom*). Extradural haematoma the day after trauma. Note considerable fairly local expansion.

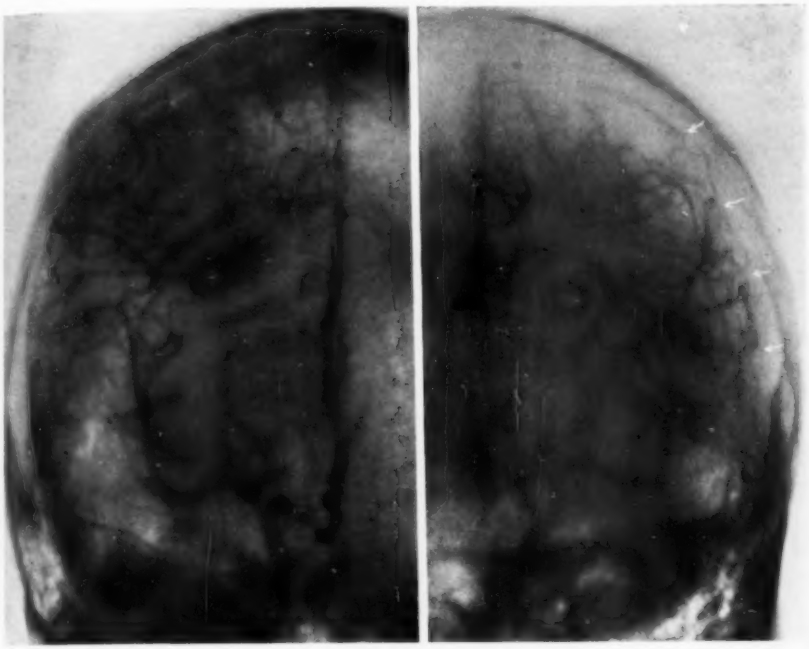


Fig. 6. Angiograms of one and the same patient taken the day after trauma. Acute subdural haematoma on left side spread out in thin layer and not deforming outline of brain. On right side signs of acute subdural haematoma seen high up over convexity, but in addition the haematoma bulges basally, thus indicating an extradural component. (Intracerebral hemorrhage partly responsible for displacement of middle cerebral artery.)

Judging by our series, a subdural haematoma with a border running more or less 'parallel' to the skull is, as a rule, at the most 3, probably only 2, weeks old, while a more bulging outline indicates that the lesion is at least two weeks old. In other words, it may sometimes be possible to decide whether a subdural haematoma is due to some injury reported or remembered by the patient — a helpful point in dealing with insurance claims.

The angiographic appearances of the extradural haematoma are also characterized by a lifting of the surface vessels of the brain from the skull (WICKBOM, ENGESET, LINDGREN). This makes it difficult to differentiate between a subdural and an extradural haematoma. Nevertheless, if it is possible to demonstrate displacement of the sagittal sinus from the lamina interna, as reported by WICKBOM, a diagnosis of an extradural

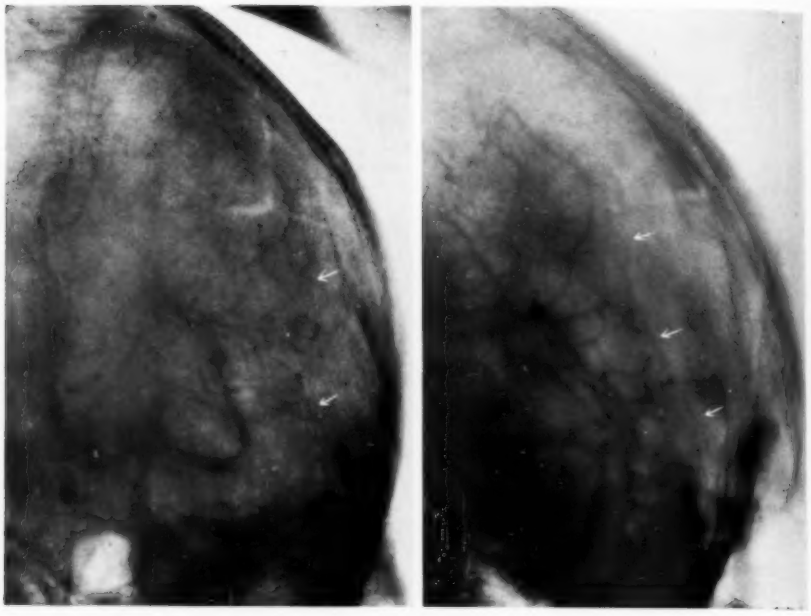


Fig. 7. Extradural haematoma. Degree of expansion is more evident in the view to the *right*, showing value of oblique views.

haematoma may be established with certainty. This appears to be the only possibility of differentiation known. However, no such case was seen in our series.

As expected, the number of cases of extradural haematoma examined arteriographically in our material is not large, and consists of only 11 cases (Diagram 2); this type of haematoma usually requires immediate surgery. The arteriograms in these cases, however, seem to present fairly uniform appearances. From the beginning they show a considerable local expansion (Fig. 5) due to the fact that, unlike the subdural, the extradural haematoma has no pre-existing space in which to spread but must tear the dura away from the skull. The roentgenographic appearances are thus more or less similar to those seen in the later stages of chronic subdural haematoma. The outline of a pure extradural haematoma is, however, more or less irregular, in other words, without the smooth concavity characteristic of the chronic subdural haematoma. Although the expansion due to an extradural haematoma is often fairly local, the area

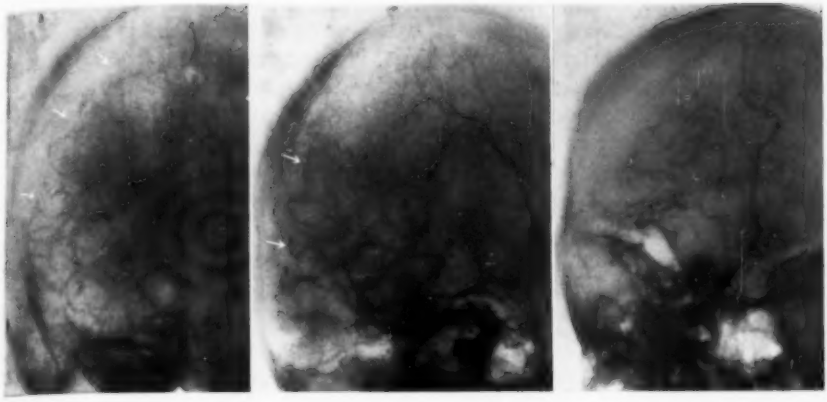


Fig. 8. Subdural haematoma 1 month after trauma. Appearances of lateral *(left)* and posterior *(middle)* regions suggest acute subdural haematoma. In frontal region *(right)*, however, marked expansion can be recognized. This is in agreement with age of lesion.

lifted from the skull may sometimes be relatively large. Such appearances suggest the co-existence of a subdural haematoma.

Patients with extradural haematomata are, of course, usually examined soon after the preceding injury. The differential diagnosis then lies between an extradural and a recent subdural haematoma. Since these two types produce different characteristic arteriograms, there is a possibility of distinguishing them. The difference in the arteriographic appearances is exemplified in Fig. 6 which shows examinations of the same patient on the day of the injury. The vessels on the surface of the brain are lifted from the skull on both sides. On the right side the expansion is fairly local and the haematoma bulges into the brain; it is thus an extradural haematoma. The haematoma on the left side is spread out to an even depth, and does not deform the outline of the brain; an acute subdural haematoma is present.

As this roentgenologic diagnosis is founded on the shape of the profile of the haematoma, one should try to obtain tangential views of the various parts of the lesion. Fig. 7 shows a case of extradural haematoma in which the degree of expansion was not evident from more than one projection, and Fig. 8 represents a case of subdural haematoma in which the expansive character was likewise apparent only in one of the oblique views. In addition, as pointed out by LINDGREN, such oblique films may be necessary to demonstrate even the presence of the lesion, particularly small ones. As far as is known, only one case has been missed in the present series.

It thus appears that not only the chronic but also the acute subdural haematoma has its own typical roentgenographic appearances which permit a rough evaluation of the age. The angiographic appearances of an acute subdural haematoma differ from those of an extradural haematoma, for which reason it should be possible to make a distinction between them.

SUMMARY

An analysis of 64 cases of subdural haematomas showed that during the first two weeks they spread evenly without deforming the shape of the outline of the brain; they afterwards showed signs of expansion and, from the fourth week, typical appearances of a chronic subdural haematoma were evident. The extradural haematoma (11 cases) consistently showed signs of considerable expansion from the beginning. These characteristics often permit the differentiation of the three types.

ZUSAMMENFASSUNG

Eine Analyse von 64 Fällen mit Subduralhämatomen zeigte, dass diese sich in den ersten 2 Wochen gleichförmig ausdehnen, ohne dabei die Form der Hirnkontur zu deformieren. Nach diesem Zeitraum wiesen sie Anzeichen eine Expansion auf und von der 4. Woche an lag das typische Bild eines chronischen Subduralhämatomes vor. Das extradurale Hämatom (11 Fälle) wies konsequent von Anfang an Anzeichen einer bedeutenden Expansion auf. Diese Charakteristika gestatten oftmals die Differentialdiagnose der drei Typen.

RÉSUMÉ

L'analyse de 64 cas d'hématomes sous-duraux a montré que, pendant les deux premières semaines, ils s'étendent régulièrement sans déformer le contour du cerveau; ils ont ensuite présenté des signes d'expansion et, à partir de la quatrième semaine, l'aspect typique d'hématome sous-dural chronique était évident. Les hématomes extra-duraux (11 cas) ont constamment présenté, dès le début, des signes d'expansion considérable. Ces caractéristiques permettent souvent le diagnostic différentiel entre les trois types.

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FROM GEMEENTEZIEKENHUISEN VAN 'S-GRAVENHAGE, HOLLAND

THROMBOSIS OF THE MIDDLE CEREBRAL ARTERY

by

A. Verjaal and *N. J. H. Neyens*

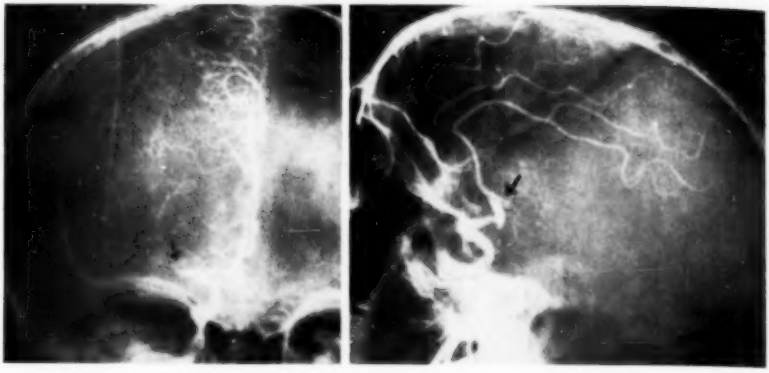
Apoplexy is a common cause for admission to hospital. The simple diagnosis of apoplexy, however, cannot satisfy the clinical neurologist, as he knows from post-mortem observations that many different conditions may underly the syndrome. The following broad clinical divisions may be made.

Haemorrhage:	*Softening:*
Haematoma;	Thrombosis;
Infiltrating haemorrhage.	Embolism;
	Unknown causes.

Clinical 'bedside' characteristics of the syndrome generally indicated as apoplexy do not permit reliable conclusions as to the pathology. Neither the onset nor the symptomatology can give us sufficient information as to whether the patient has cerebral haemorrhage or softening. Lumbar puncture, however, usually will readily distinguish between the two. When the cerebrospinal fluid contains no blood or markedly increased protein, softening is very likely to have occurred. In most cases, further localisation of the vascular occlusion is possible by means of angiography.

Regarding one aspect of angiography: thrombosis of the middle cerebral artery gives a very typical picture, characterized in the lateral projection by satisfactory filling of the anterior, and eventually the posterior cerebral artery, while there is merely a small stump in the region where the middle cerebral artery would be expected to branch off. In the a. p. projection the block in the middle cerebral artery is visible about one cm from the origin of the artery, this being the obvious site of predilection.

Thrombosis of the middle cerebral artery in itself is not a final diagnosis. It would be an error to assume that arteriosclerosis is the only cause. Middle cerebral artery thrombosis may occur as a complication in different conditions. The angiograms of such cases present alike pathognomonic appearances, again and again, which to some extent make



Angiograms in a typical case of thrombosis from the material.

them monotonous; a monotony, however, largely relieved by the divergence of the underlying causes and the variety of clinical signs. In the figure, one example of a typical case in our material is demonstrated.

Six of our 10 patients had hemiplegia, hemianopsia and hemihypaesthesia, 2 had isolated hemiparesis, and the remaining 1 showed no paretic signs whatsoever. One of the patients had receptive aphasic disturbances and one a homonymous hemianopsia. In six patients middle cerebral artery thrombosis was preceded by, combined with, or followed soon after by venous thrombosis in one leg. The primary diseases which were considered responsible for the condition in our ten cases were: arteriosclerosis (4); hypertension (1); renal tuberculosis (1); carcinoma of the pancreas (1); endarteriitis Buerger (1); syphilis (1), and abscess of the thoracic wall (1).

SUMMARY

Middle cerebral artery thrombosis cannot be diagnosed by clinical methods. In the cerebral angiogram it presents pathognomonic appearances. It may occur as a complication of vascular, inflammatory, or neoplastic conditions, situated anywhere in the body.

ZUSAMMENFASSUNG

Die Thrombose der Arteria cerebri media kann klinisch nicht diagnostiziert werden. Im zerebralen Angiogramm hat sie ein pathognomisches Aussehen. Sie kann als eine Komplikation vaskulärer, entzündlicher oder maligner Zustände auftreten, die irgendwo im Körper vorhanden sind.

RÉSUMÉ

Le diagnostic de la thrombose de l'artère cérébrale moyenne est impossible par les méthodes cliniques. Elle présente sur les angiographies cérébrales des aspects pathognomoniques. Elle peut survenir comme complication d'affections vasculaires, inflammatoires ou néoplastiques situées n'importe où dans le corps.

AUS DER NERVENKLINIK DER STADT UND UNIVERSITÄT FRANKFURT A. M. (DIREKTOR: PROF. DR. J. ZUTT), FRANKFURT A. MAIN, DEUTSCHLAND

ANGIOGRAPHISCHE BEFUNDE BEI CEREBRALEN GEFÄSSERKRANKUNGEN UND IHRE BEZIEHUNGEN ZU DEN KLINISCHEN SYNDROMEN

von

R. Frowein

In meinen Ausführungen möchte ich mich mit der Gruppe von cerebralen Gefässerkrankungen befassen, die im Angiogramm eindeutige Durchblutungsstörungen im Carotisgebiet erkennen lassen, nämlich dadurch, dass bestimmte Gefässversorgungsgebiete entweder einen völligen Ausfall der Durchblutung oder aber eine deutliche Durchblutungsbehinderung aufweisen. Es sind dies also einerseits Fälle mit mehr oder weniger umschriebenen und mehr oder minder kompletter Obliteration einer Arterie und andererseits Erkrankungen, die durch diffusere Gefässveränderungen in kleineren oder grösseren Gefässbereichen zu Kalibereinengungen oder gar -verschlüssen und damit wiederum zur Durchblutungsbehinderung führen. Von derartigen Fällen werden einige charakteristische Angiogramme demonstriert, und dabei wird diskutiert, inwieweit sich angiographisches Bild und klinische Symptome einander zuordnen lassen. Ätiologische Gesichtspunkte sollen dabei nur zu Sprache kommen, soweit sie für die vorliegende Fragestellung von Bedeutung sind.

Wenden wir uns zunächst der Frage zu, welche klinischen Symptome bei den Patienten zu beobachten sind, bei denen sich im Angiogramm totale oder partielle Durchblutungsbehinderungen nachweisen lassen. Es erschien mir in diesem Zusammenhang vorteilhaft, die klinischen Bilder nicht nach einzelnen Symptomen zu ordnen, sondern nach charakteristischen Syndromen. Dabei wird auf die Ergebnisse der Untersuchungen von Foix und seinen Schülern zurückgegriffen. Foix hat ja bekanntlich auf Grund von klinischen und anatomischen Studien Verschluss-Syndrome für die verschiedenen Hirnarterien beschrieben. Auf Grund dieser Beob-

achtungen lassen sich die Erweichungsherde und Syndrome im Gebiet der Art. cerebralis media wie folgt charakterisieren.

Eine totale Sylviaerweichung ist bedingt durch einen Verschluss des Sylviaursprunges selbst. Es kommt dabei zu einer Erweichung des gesamten Versorgungsgebietes der Sylvischen Gefässgruppe. Klinisch bestehen schwerste Hemiplegie, Hemianästhesie, Hemianopsie, sowie bei linksseitiger Lokalisation eine Aphasie. Die grosse zentrale Sylviaerweichung wird bedingt durch eine mehr oder weniger komplette Obliteration des Sylviastammes an seinem Ursprung, durch die das Versorgungsgebiet der Artt. perforantes zerstört wird. Das klinische Bild ist gekennzeichnet durch eine totale proportionale Hemiplegie ohne, oder fast ohne, Sensibilitätsstörungen und ohne Hemianopsie. Bei linksseitiger Läsion tritt eine Aphasie hinzu. Die partielle zentrale Sylviaerweichung entspricht der Läsion der Rami perforantes von der Putamino-Capsulo-Caudatusgruppe. Klinisch besteht eine ziemlich proportionale Hemiplegie, sowie bei linksseitigem Sitz eine vorübergehende Sprachstörung. Die grosse oberflächliche Sylviaerweichung entsteht durch schwere Läsion des Sylviastammes jenseits des Abganges der Artt. perforantes, durch die vorwiegend das Versorgungsgebiet der Artt. ascendentes erweicht wird. Klinisch bestehen eine Hemiplegie vom armmonoplegischen Typ mit Hemianästhesie in analoger Verteilung, sowie bei linksseitiger Lokalisation eine vorwiegend motorische Aphasie, Lese- und Schreibstörung sowie Rechenstörung. Die sehr häufige hintere Sylviaerweichung entsteht durch Läsion des hinteren Sylviastammes, also nach dem Abgang der Artt. ascendentes, und führt zu einer Erweichung des Versorgungsgebietes der Artt. parietalis posterior, Gyri angularis und temporalis posterior. Klinisch besteht ein parieto-temporo-angulares Syndrom, bei rechtsseitigem Sitz fast nur eine Hemianopsie, bei linksseitigem Sitz noch eine schwere sensorische Aphasie und apraktische Erscheinungen.

Besonders wichtig zum Verständnis der klinischen Bilder ist die Feststellung von Foix, dass sowohl bei kompletter als auch bei partieller Obliteration einer Arterie, die der Obliterationsstelle am nächsten gelegenen Gewebspartien am schwersten, die distalen Versorgungsgebiete dagegen verhältnismässig wenig betroffen werden. Dieses von Foix aufgestellte Gesetz ist von besonderer Bedeutung gerade für die Sylvialäsionen insofern, als bei Obliterationen in deren Anfangsteil die Versorgungsgebiete der proximalen Äste, also besonders der Artt. perforantes und ascendentes betroffen werden, während das hintere Versorgungsgebiet in der Regel verschont bleibt. Eine Bestätigung dieser Foix'schen Regel werden wir auch bei später zu demonstrierenden Fällen finden.

Nach meinen Erfahrungen erscheint es aufschlussreich, ausgehend von den Ergebnissen der Foix'schen Schule, zu versuchen, die klinischen Bilder bei cerebralen Durchblutungsstörungen in entsprechende Syndrome

einzuteilen, und so zu untersuchen, wie sich angiographischer Befund, mutmassliche bzw. in einzelnen Fällen autoptisch oder bioptisch bestätigte anatomische Läsion und klinisches Bild einander zuordnen lassen.

Unter 16 eigenen einschlägigen Fällen mit Carotisverschlüssen, teils im Bereich der Teilungsstelle, teils im Bereich des Syphons, wiesen alle Patienten bis auf einen eine reine Media-Symptomatologie auf. Dies entspricht den Erfahrungen anderer Autoren und ist, wie bekannt, dadurch zu erklären, dass in der überwiegenden Mehrzahl der Fälle die Anterior der einen Hemisphäre über die Communicans anterior genügend Blut auch von der anderen Seite her zugeführt bekommt, sodass es beim Verschluss der gleichseitigen Carotis zwar zu Ernährungsstörungen im Mediabereich, in der Mehrzahl der Fälle aber nicht im Anteriorversorgungsgebiet kommt. Für das Ausmass der Gewebsschädigung bei den Carotisverschlüssen, und damit für deren Symptomatologie, ist ferner, wie bekannt, die Tatsache von Bedeutung, dass in einem individuell verschiedenen Ausmass Blut aus dem Vertebraliskreislauf über die Communicans posterior in den Carotiskreislauf strömen kann. Auch die Geschwindigkeit, mit der der Verschluss erfolgt, spielt eine Rolle.

Bei unseren Patienten mit Carotisverschlüssen lagen vier Mal eine totale Sylviaerweichung, sechs Mal eine grosse zentrale Sylviaerweichung, zwei Mal eine partielle zentrale Sylviaerweichung, und drei Mal eine oberflächliche Sylviaerweichung vor. In einem Fall bestanden neben den Symptomen einer totalen Sylviaerweichung auch Krankheitserscheinungen, die auf eine zusätzliche Schädigung des Anteriorbereiches schliessen liessen. Durchweg waren die klinischen Ausfallserscheinungen bei den totalen Carotisverschlüssen schwerer als bei den partiellen Verschlüssen. Bei eindeutig partiellen Verschlüssen wurde eine totale Sylviaerweichung nicht beobachtet. Schliesslich konnte an dem eigenen Material auch die schlechte Prognose der totalen Sylviaerweichungen bestätigt werden. Bei allen Todesfällen unter den Carotisverschlüssen hatte eine totale Sylviaerweichung vorgelegen.

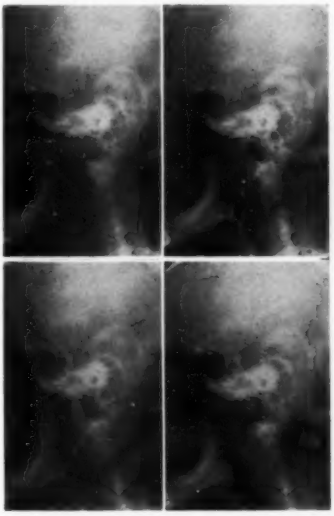


Abb. 1. Fall 1. Carotisverschluss. Seitliche Angiogramme, rechter Seite, aus einer Odelca-Serie. Füllung der Art. carotis externa. *Unten rechts:* Hauptstamm der Externa schon wieder leer.

Fall 1. 58-jähriger Mann mit einer proportionalen spastischen Hemiplegie links, halbseitigen Sensibilitätsstörungen links, sowie eine homonyme

Abb. 2. Derselbe Fall als in Abb. 1. *Oben:* A. p.-Projektion. *Unten:* Angiographie der linken Seite.

Hemianopsie nach links, ferner eine Gesichtsapraxie, während sonst apraktische Störungen nicht nachweisbar waren. Es dürfte also bei dem Kranken eine totale Sylviaerweichung auf der rechten Seite eingetreten sein. Bilder aus einer Odelca-Serie werden in Abb. 1—2 gezeigt. Die Punktionsnadel liegt in der rechten Carotis communis dicht unterhalb der Teilungsstelle. Im Verlauf der Injektion füllt sich die Art. carotis externa. Auf Abb. 1 (unten rechts) ist der Hauptstamm der Externa schon fast wieder leer. Von der Art. carotis interna sieht man höchstens einen stummelförmigen Ansatz. Sie ist an dieser Stelle völlig verschlossen. Trotz nicht unerheblicher Veränderungen am Carotissiphon links sind die Durchblutungsverhältnisse normal. Die rechte Anterior ist deutlich mitgefüllt. Sogar die Media auf der rechten Seite zeigt eine gewisse Füllung.

Fall 2. 46-jähriger Mann mit Durchblutungsstörung im Mediagebiet, einer nicht sehr erheblichen spastischen Hemiparese rechts und motorische Aphasie. Es handelt sich also um ein Syndrom, das auf eine partielle zentrale Sylviaerweichung mit teilweisem Übergreifen auf das oberflächliche Gebiet zurückzuführen sein dürfte. Wie es in Abb. 3 gezeigt ist, handelt es sich um einen Verschluss der Art. cerebralis media links. Die Art. cerebralis anterior — und über die Communicans posterior auch die Art. cerebralis posterior — sind gut gefüllt (Abb. 3 oben rechts). In der a. p.-Projektion lässt sich die genauere Lokalisation des Verschlusses erkennen, nämlich am Ursprung der Media vor dem Abgang der Artt. perforantes.

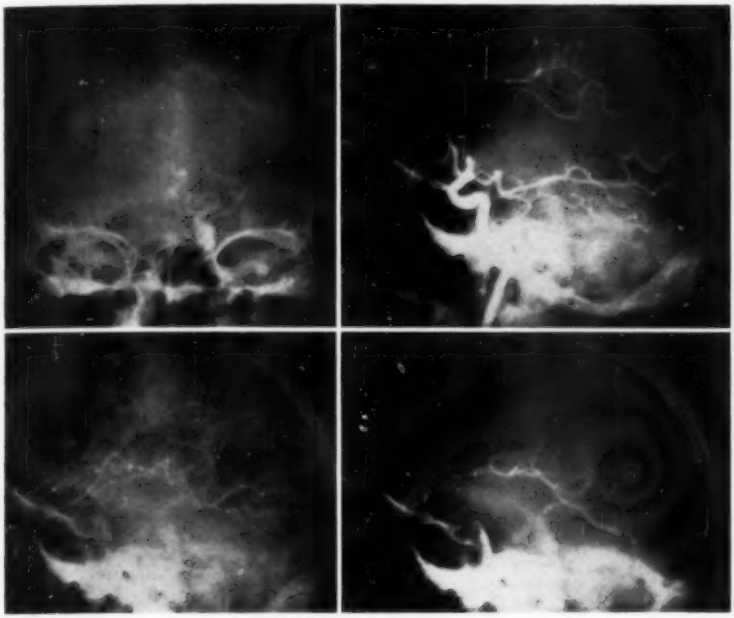


Abb. 3. Fall 2. *Oben:* A. p.-Projektion. Lokalisation des Verschlusses der Art. cerebralis media (links Artt.) cerebralis anterior und posterior gut gefüllt (rechts). *Unten:* Füllung der Mediaäste (links); die venöse Phase im gesamten Bereich der Hemisphäre (rechts).

Wir haben hier eine Bestätigung der FOIX'schen Regel. Es ist nämlich nur das Versorgungsgebiet der dem Verschluss zunächst liegenden Artt. perforantes, und teilweise der Artt. ascendentes betroffen, während das hintere Versorgungsgebiet verschont geblieben ist. Eine Kontrolle der Angiographie 8 Monate später ergab praktisch die gleichen Durchblutungsverhältnisse. Mit Hilfe einer Schnellserie lassen sich die Durchblutungsverhältnisse bei dem Kranken noch eindeutiger analysieren. Artt. cerebri anterior und posterior füllen sich im normalen Tempo. Der Mediabereich dagegen ist nach 1.5 Sek. noch nicht dargestellt. Erst nach 2 Sek. zeigt sich dann ziemlich plötzlich eine Füllung der Arterien der Sylvischen Gefässgruppe, und zwar erkennt man sie zunächst im oberen Parietalbereich, dann in der hinteren Temporalregion, schliesslich auch retrograd weiter zum Sylviaursprung hin. Eine Sekunde nach Entleerung von Artt. anterior und posterior sind nun auch die Sylvischen Arterien wieder entleert. Auch in der venösen Phase ist die Durchblutung im Mediabereich um über 1 Sek. verzögert. Man erkennt dies deutlich an

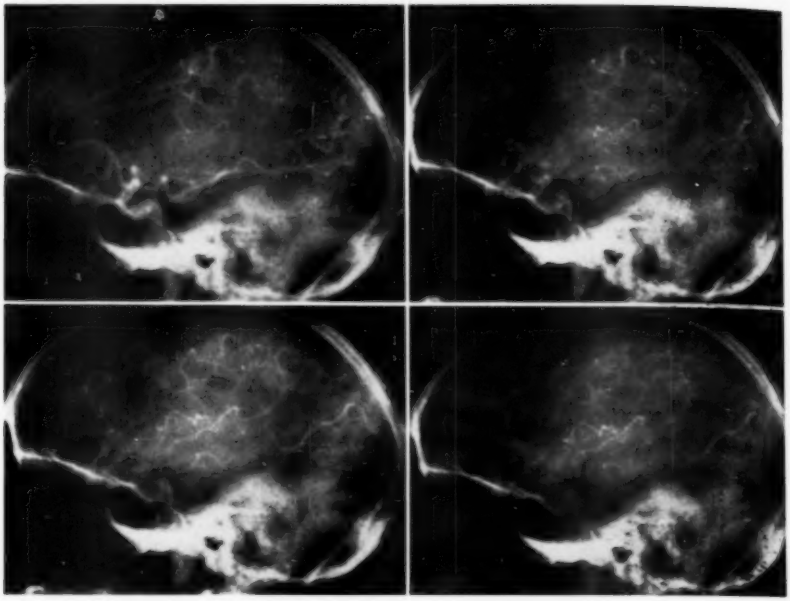


Abb. 4. Derselbe Fall als in Abb. 3, 8 Monate später. Ausschnitte aus der Odelca-Schnellserie, hergestellt mit 4 Bildern pro Sek., insgesamt 40 Aufnahmen. Die Äste der mittleren Hirnarterie durch eine Kollateralkreislaufbildung retrograd von der Artt. cerebralis anterior und posterior her gefüllt.

den Venen in der Temporo-occipital-Region. Ausschnitte aus der Odelca-Schnellserie werden in Abb. 4 gezeigt.

Fall 3. 48-jährige Patientin, bei der auf Grund einer Hirnembolie eine fast proportionale linksseitige spastische Hemiplegie ohne Sensibilitätsstörungen und ohne Hemianopsie entstanden war. Es dürfte sich also im wesentlichen um eine grosse zentrale Sylviaerweichung gehandelt haben. Das Angiogramm (Abb. 5), das etwa 19 Monate nach dem Insult angefertigt wurde, zeigt eine partielle Durchblutungsstörung im gesamten Mediabereich rechts; auch hier also entsprechend der Foix'schen Regel eine Erweichung in den dem Verschluss zunächst gelegenen Gewebspartien.

Das initiale klinische Bild war bei dieser Kranken wesentlich schwerer als bei dem Falle 2 und zeigt auch eine viel geringere Rückbildungstendenz. Dieser scheinbare Widerspruch zwischen Schwere der klinischen Bilder einerseits und der angiographisch erkennbaren Durchblutungsstörungen andererseits kann wie folgt erklärt werden. Bei der zuletzt genannten Patientin handelte es sich um ein plötzlich einsetzendes Krankheitsbild auf Grund einer Embolie mit einem vermutlich weitergehendem Verschluss, als jetzt angiographisch nachweisbar ist, nachdem

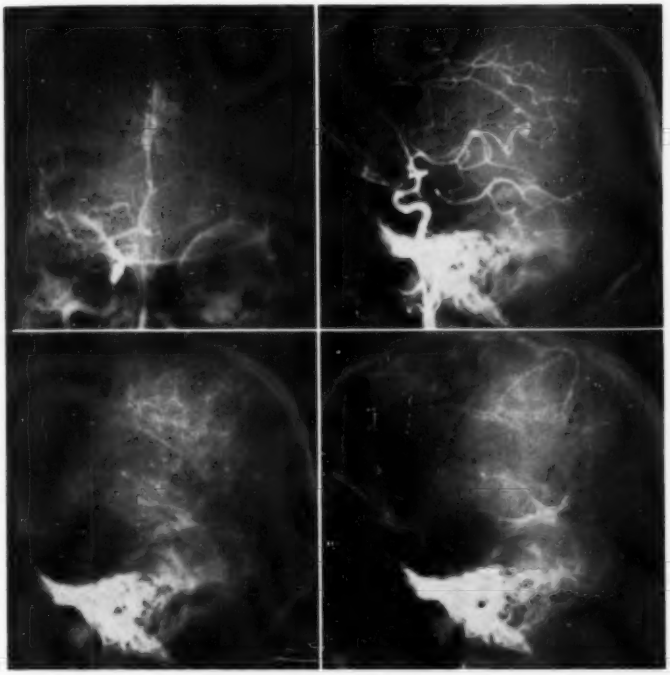


Abb. 5. Fall 3. Durchblutungsstörung im gesamten Mediabereich. *Oben:* Arterielles a. p.-Bild. Verengung des Lumens des Mediastammes unmittelbar nach dem Abgang aus der Carotis. Durchblutung im Bereich der Sylvischen Gefässgruppe (rechts) deutlich gegenüber Anterior und Posterior zurückbleibend. *Unten links:* Mediaäste dargestellt im Gegensatz zu Anterior und Posterior.

die wahrscheinlich zusätzliche angiospastische Komponente weggefallen und möglicherweise auch eine teilweise Rekanalisierung eingetreten sind. Bei dem Falle 2 dagegen, bei dem eine Bürgersche Krankheit besteht, waren dem Insult schon längere Zeit gleichartige, aber nur flüchtige Symptome voraus gegangen, sodass der Verschluss allmählich entstanden sein dürfte und Zeit bestand zur Ausbildung eines Kollateralkreislaufes, der dann auch angiographisch nachweisbar war.

Fall 4. 48-jähriger Mann, der, wie die spätere Obduktion ergab, an einer Arteriitis litt. Klinisch bestanden bei dem Kranken eine spastische Hemiparese links mit deutlicher Betonung der Lähmungserscheinungen am Arm, sowie eine Hemihypästhesie links. Auf Grund dieses Syndroms war im wesentlichen eine oberflächliche Sylviaerweichung anzunehmen. Das Vorliegen derselben konnte dann später bei der Obduktion bestätigt werden. Das Angiogramm zeigte eine Durchblutungsstörung vorwiegend im Bereich der Artt. ascendentes rechts. Diese waren, wie sich aus den weiteren Serienaufnahmen

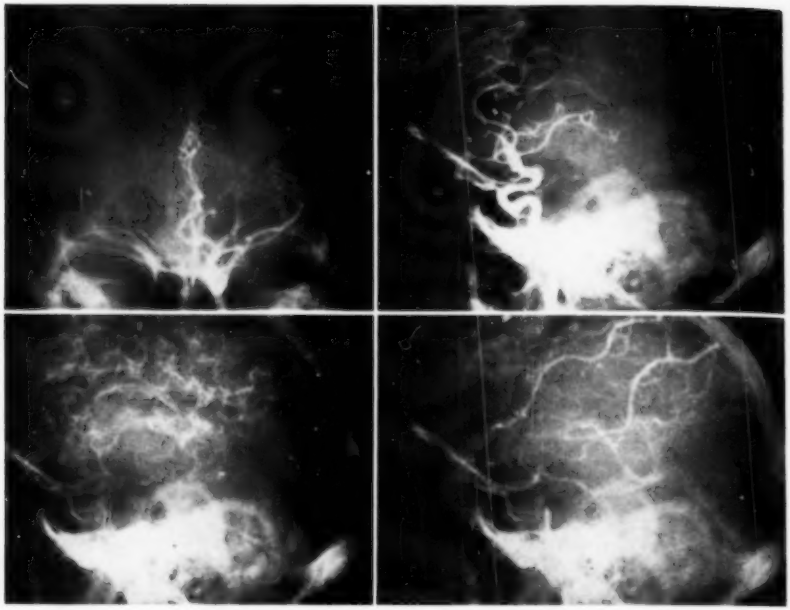


Abb. 6. Fall 6. Ausfall des hinteren Sylviastammes. *Oben:* Artt. ascendentes zeigt geringe Durchblutungsbehinderung. Die hinteren Sylviaäste fehlen, sowie die Venen in der Temporo-occipital-Region.

ergab, praktisch völlig ausgefallen. Von der hinteren Sylviagruppe fehlte die Art. parietalis posterior. Die übrigen Äste zeigten Kaliberauffälligkeiten, waren aber sonst noch ausreichend durchblutet.

Fall 5. 25-jähriger Mann mit einer partiellen aber deutlichen Durchblutungsbehinderung im Mediabereich links und zwar im wesentlichen die Artt. parietalis anterior und parietalis posterior, sowie offenbar auch Äste der Art. gyri angularis betreffend, während die übrigen Mediaäste keine gröberen Auffälligkeiten erkennen liessen. Klinisch handelte es sich im wesentlichen um eine Leitungsaphasie, Schreib-, Lese- und Rechenstörungen, also um Symptome, die sich durch eine Erweichung im Versorgungsgebiet der genannten Arterien erklären lassen.

Fall 6. (Abb. 6.) 62-jähriger Kranken mit totalem Ausfalle des hinteren Sylviastammes. Klinisch bestanden eine sensorische Aphasie, Schreib- und Lesestörung, eine homonyme Hemianopsie nach rechts, sowie geringe Sensibilitätsstörungen und eine geringe Schwäche am rechten Arm, also im wesentlichen das Syndrom einer hinteren Sylviaerweichung, beruhend auf einem Verschluss des hinteren Sylviastammes und — entsprechend den Durchblutungsverhältnissen — nur geringe Symptome von seiten des Versorgungsgebietes der Artt. ascendentes. Während die Artt. perforantes unauffällig sind und die Artt. ascendentes nur eine geringe Durchblutungsbehinderung zeigen, (ihren Stamm erkennt man gut in der a. p.-Projektion) fehlen die hinteren Sylviaäste völlig. Auch die Venen in der Temporo-occipital-Region sind nicht dargestellt. Als Nebenbefund finden sich ältere flächenhaft angeordnete fleckförmige Verkalkungen in den Meningen über Konvexität links.

Ich habe die Beispiele aus dem Bereich der Sylvischen Gefässgruppe ausführlicher gebracht, weil sie mir besonders aufschlussreich zu sein scheinen. Die Ergebnisse können wie folgt zusammengefasst werden.

Gerade auch für die Angiographie bei cerebralen Gefässaffektionen ist die Anfertigung von Serienaufnahmen unerlässlich. Nur durch eine funktionelle Angiographie ist eine sichere Beurteilung der tatsächlichen Durchblutungsverhältnisse möglich. Eine weitere Verbesserung der diagnostischen Möglichkeiten kann man durch Schnellserien, wie sie z. B. mit der Odelca-Kamera möglich sind, erwarten, weil mit ihnen die Einzelheiten des Durchblutungsablaufes, vor allem auch bei geringgradigeren Störungen, noch besser zu erfassen sein dürften. Auf der anderen Seite erscheint die Heranziehung klinisch-anatomischer Beobachtungen und Erfahrungen für die richtige Bewertung der angiographischen Befunde bei cerebralen Durchblutungsstörungen von grossem Wert. Die Berücksichtigung dabei festgestellter Gesetzmässigkeiten ermöglicht in vielen Fällen eine Zuordnung der klinischen Bilder zu den Angiogrammen und gestattet es, bestimmte Syndrome herauszustellen.

ZUSAMMENFASSUNG

Cerebrale Gefässerkrankungen, die im Angiogramm eindeutige Durchblutungsstörungen im Carotisgebiet erkennen lassen, sodass bestimmte Gefässversorgungsgebiete entweder einen völligen Ausfall der Durchblutung oder/aber eine deutliche Durchblutungsbehinderung aufweisen, werden diskutiert und mit Beschreibungen von sechs Fällen erleutert. Eine weitere Verbesserung der diagnostischen Möglichkeiten kann man durch Schnellserien erwarten, weil mit ihnen die Einzelheiten des Durchblutungsablaufes, vor allem auch bei geringgradigeren Störungen, noch besser zu erfassen sein dürften.

SUMMARY

Cerebral vascular diseases which may be shown by angiography to lead to significant disturbances in the blood circulation in the region of the caroticus are discussed and exemplified by six cases. It is pointed out that certain regions of vascularization either become entirely eliminated or else show a distinct deficiency of circulation. It seems possible that the diagnostic possibilities may be further improved by the use of rapid serial films, which should enable details of the vascular circulation to be more clearly observed, especially when the disturbances are of small magnitude.

RÉSUMÉ

L'auteur étudie et illustre par la présentation de six cas les maladies vasculaires cérébrales qui se traduisent sur l'angiographie par d'importantes perturbations de la circulation dans le territoire carotidien, amenant dans certains territoires vasculaires soit une suppression complète, soit une gène évidente de l'irrigation sanguine. On peut attendre de la sério-angiographie rapide un nouveau progrès des possibilités de diagnostic, car elle permet d'étudier encore mieux les détails de la circulation sanguine, surtout quand ses perturbations sont minimes.

FROM THE NEUROSURGICAL CENTRE (DIRECTOR: PROF. A. MARCEL DAVID; DIRECTOR OF THE ROENTGEN DEPARTMENT: DR. GIOVANNI RUGGIERO) OF THE STE-ANNE HOSPITAL, PARIS, FRANCE

THE ROENTGENOLOGIC CONTRIBUTION TO STEREOTAXIC INVESTIGATIONS OF THE BRAIN AND ITS PRACTICAL APPLICATION IN PATHOLOGIC CONDITIONS

by

J. Talairach, G. Ruggiero and *M. David*

Stereotaxic surgery has for some years been used in the treatment of certain functional disorders of the nervous system and, more recently, of certain brain tumours shown to be practically unamenable to the usual surgical methods.

Stereotaxic investigation consists in defining in space the position of a point within the cranial cavity, which is to be reached for therapeutic purposes. It involves the solution of a fundamental anatomic problem — the accurate localization of a normal or pathologic structure. A second technical problem of constructing and using the necessary apparatus arises as a corollary of the first. Radiologic factors play a primary rôle in the method, as will be shown in this paper. We shall not deal with stereotaxic apparatus, the technique of stereometry, or the stereotaxic operation.

Technique for obtaining true images

A fundamental element in stereotaxic investigations is the actual size of the structures shown in the roentgenogram. This may be determined by:

1) the representation of a true image directly in the film;

2) calculation.

Our efforts from the beginning have been devoted to the first method. We have employed teleroentgenography at a focus—film distance of 4.25 m (approx. 14 feet). The advantage of such a procedure is to permit exact

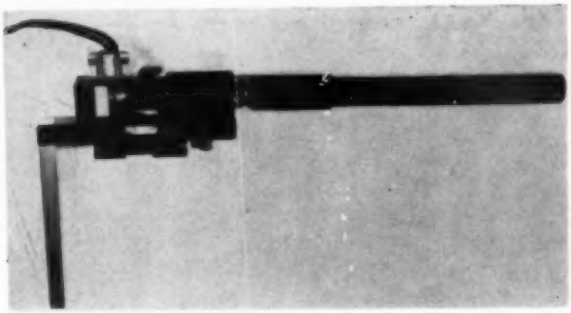


Fig. 1. Telescopic sight for teleroentgenography.

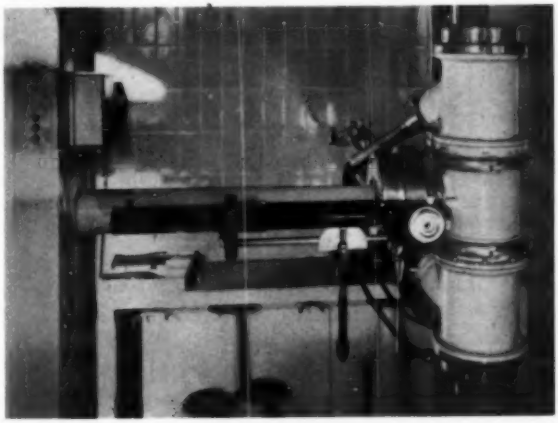


Fig. 2. The sighting apparatus applied for teleroentgenography.

measurements of the position of a structure in relation to the superimposed image of the stereotaxic frame. Moreover, this procedure allows rapid and easy verification of the position of structures during their stereotaxic localisation, or of the position of the electrodes during stereotaxic surgery.

Among the procedures based on the second method, that of VERNON, MCPHERSON and SWEET has the advantage of allowing free radiologic manipulations during the procedure; this is offset by the fact that the films cannot be read off directly, and the control particularly during operation becomes complicated. Teleradiography has the advantage of making the stereotaxic method of treatment of tumours more simple. The limitation of radiologic manipulations, a disadvantage of our method,

may be overcome by a special stand with a tube capable of wide range angulation at the focus—film distance of 4.25 m.

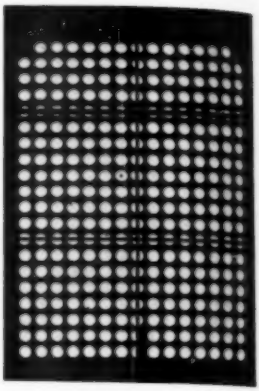


Fig. 3. Teleroentgenogram of a double grill. Central ray directed through inferior sector. Note difference between perforation of this sector and those of upper sector, which are distorted.

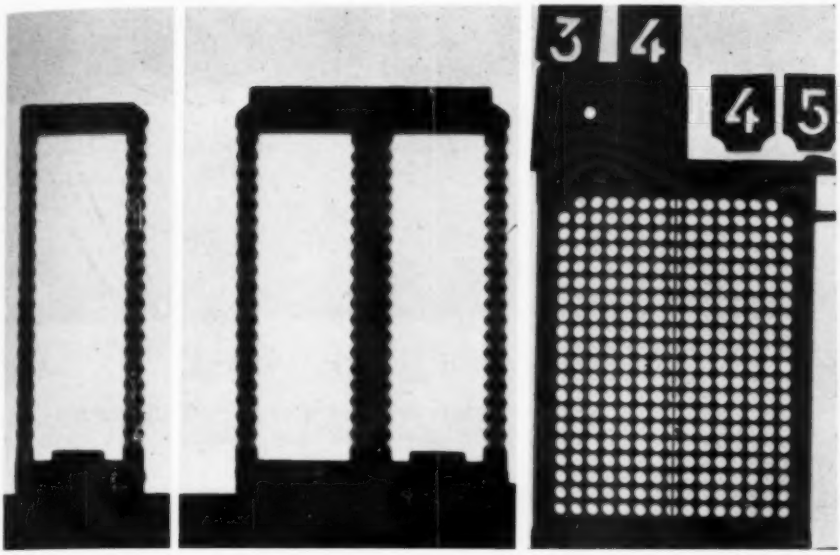
Technique of teleradiography

Teleroentgenography with the narrowest possible beam is, in effect, roentgenography with parallel radiation. The central ray must pass through the centre of the structure to be examined, and lie perpendicular to the sagittal plane of the skull and to the stereotaxic frame. The images are thus not appreciably distorted or displaced in relation to each other. A special centring device is employed. It consists of two parts. One is attached to the roentgen tube and serves as a telescopic sight (Fig. 1); it is 46 cm in length, its axis lying parallel to the beam. The second, the position of which can be varied to suit the roentgenographic field, is fixed to the stereotaxic frame (Fig. 2), perpendicular to its sagittal plane. It is made up of a hollow tube, 30 cm long, with luminous discs at each end. By means of the telescopic sight it is easy to focus on this tube and to adjust the roentgen tube so that the two luminous discs coincide. The radiation will then enter the skull parallel to the horizontal and perpendicular to the sagittal plane.

Each important projection is checked by the method of the 'double grill'. This consists of obtaining another film in the same position but with a grill placed on the stereotaxic frame in relation to the zone to be examined. This grill (Fig. 3) consists of two absolutely symmetrical plates, 5 cm apart, with multiple perforations at 1 mm distances in each. The midline of each plate is marked by a steel thread running from the upper to the lower borders and is further divided into three parts by two steel threads running horizontally across the plate, adjustable in such a way that the centring may be varied depending on whether the structure to be examined is situated towards the upper or lower part of the grill.

The grill should be seen in the roentgenogram as a single structure, that is to say, the two plates should be superimposed; the perforations of one plate will coincide exactly with those of the other. Any error in the teleroentgenographic procedure will thus be excluded.

This method is sufficiently accurate, even for the roentgenographic representation of a structure in the centre of the cranial cavity. In Figs.



Figs. 4 and 5. Lateral and frontal roentgenograms of a grill and a double grill. Central ray directed through centers. Perforations at periphery are slightly deformed compared with those at center.

4 and 5 such a structure is represented by a grill situated half way between the roentgen film and the double grill. There is no measurable distortion within an area of 3 cm × 3 cm at the centre of the grill (Fig. 5). Even if the whole width of the grill (4.5 cm) is used, there is only a displacement of 0.25 mm on each side. If the whole height of the grill is used, there is a displacement of 0.5 mm at its upper and lower borders. Even these extremely small errors may be corrected, as they are symmetrically disposed on either side of the centre of the grill; they would in effect enter into the calculation only when the size of the structure exceeded that of the central (accurate) part of the grill. In the latter case, however, it would be simpler to take two films, one centred on the posterior and one on the anterior part of the structure and thus avoid this source of error completely.

Inaccuracies of localizing intracranial structures by bony landmarks

For the last six years we have insisted on the inaccuracy of the localization of intracranial structures from osseous base lines in the course

of standard radiologic examination of the skull. This view now appears to be endorsed by the majority of authors.

Anatomic study under stereotaxic conditions has shown us that the intracranial structures do not bear a sufficiently exact relation to the bony base lines; they vary in their size, shape, and position, within the cranial cavity, and there is no exact proportionality between these variations and those of the skull. These variations become increasingly important the higher the structure is situated in the telencephalon.

Moreover, the anatomic problem is further complicated in disease. By virtue of the normal and pathologic variations, stereotaxic localization must have a character of its own.

Localization of intracranial structures

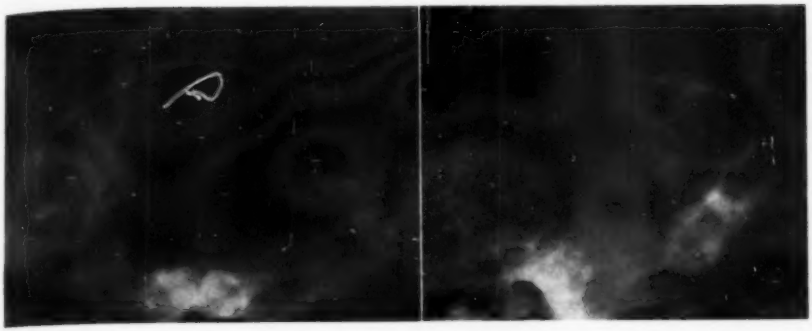
The roentgenographic localization of intracranial structures may be achieved by two methods.

1) If the structure is in contact with the subarachnoid or ventricular space it is possible to utilise the images of these to localize the structure. We call this procedure 'direct localization'.

2) If the structure is situated away from the subarachnoid or ventricular space, one must study its relationship to those neighbouring structures which may be localized directly. This implies the establishment of anatomo-radiologic base lines from which it will be possible to construct horizontal, sagittal, and coronal co-ordinates and thus permit stereotaxic measurements. We call this procedure 'indirect localization'.

Before proceeding further, we wish to emphasize certain important points in the technique.

The radiologic examination which affords the maximum amount of anatomic information is fractional encephalography. In stereotaxic investigations the structures must be as clear as possible. It is therefore preferable that the part of the ventricular and subarachnoid system examined should contain the minimum possible amount of contrast medium to avoid superimposition of unwanted structures. This implies certain special manoeuvres. Gaseous contrast medium alone is not sufficient for stereotaxic investigations, but must be supplemented with a positive heavy contrast agent; it is not possible with our apparatus to manoeuvre the patient's head into the necessary positions, and for the establishment of exact base lines certain structures must be seen with a degree of sharpness unobtainable with gas. In general, it is the inclined portions of the ventricular system which require positive contrast medium for visualization, whereas the parts situated higher up as well as the cisterns need gas for their demonstration.



Figs. 6 and 7. Direct reproductions of the anterior and middle part (*left*), and of posterior part (*right*) of cistern of corpus callosum.

Direct localization. In general, all telencephalic structures may be localized directly; in effect, the cerebral gyri vary so much that all efforts to localize them indirectly with the aid of base lines seem futile. At least this is the conclusion we have reached from our anatomic studies to date; it is therefore necessary to observe with great care the cavities containing cerebro-spinal fluid which are in contact with these structures. It may be considered easy to visualize all the cisterns and sulci by fractional encephalography; nevertheless, from a stereotaxic point of view, we consider we can define constantly and with accuracy only the structures mentioned below.

The corpus callosum, the outer border of which is clearly indicated by the pericallosal cistern (Figs. 6 and 7), the genu, body and splenium all being equally well seen. The inferior surface of the corpus callosum cannot be shown. The inferior surface of the posterior pillars of the fornix are identified by the sub-trigonal cistern lying just below (Fig. 11).

The cingulate gyrus can be identified by the sulcus cinguli (callosomarginal sulcus) (Fig. 8); this sulcus is sometimes ill-defined at its origin. Its terminal portion is often well seen and permits identification of the posterior part of the paracentral lobule. The superior frontal gyrus is also very well identified by its corresponding sulcus, which is generally well seen, even in its initial portion.

The limits of the praecuneus are defined in front by the terminal ascending portion of the sulcus cinguli, behind by the parieto-occipital fissure, and below by the cistern of the corpus callosum.

The medial surface of the occipital lobe may be defined anteriorly by the parieto-occipital fissure and inferiorly by the subarachnoid space found on the superior surface of the cerebellum. The cuneus may be defined by the parieto-occipital fissure and the calcarine fissure (Fig. 9).

The Sylvian fissure permits the recognition of the lower limits of the frontal and parietal lobes. At its termination is located the supramarginal gyrus; at its origin it is possible to locate the sulci which delineate the pars orbitalis and the pars triangularis of the inferior frontal gyrus (Fig. 10). In frontal views it also defines the outer border of the insula.

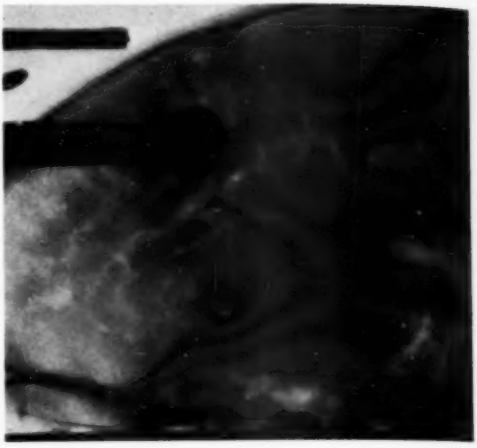


Fig. 8. Direct reproduction of sulcus cinguli. Cistern of corpus callosum and sulcus of superior frontal gyrus are also seen which permits visualization of superior frontal gyrus and of gyrus cinguli.

For visualization of the subarachnoid spaces, necessary for the identification of the structures which we have just described, we sometimes have to deviate from the rules of the standard technique of fractional encephalography and introduce special manoeuvres. The cistern of the corpus callosum cannot always be seen by a simple change from the sitting to the supine position. In effect, the beginning of the cistern of the corpus callosum makes a rather narrow angle with the upper part of the lamina terminalis. There may consequently not be enough time

Figs. 9 and 10. Direct reproductions of parieto-occipital sulcus and of calcarine fissure limiting the cuneus (*left*), and of Sylvian fissure, profile view (*right*).

Fig. 11. Direct reproduction of subtrigonale cistern.

for the passage of the gas, especially in those cases in which the sub-frontal subarachnoid spaces are rather large and aspirate the contrast medium rapidly. It is therefore necessary to keep the patient for some time in a posture which allows the air to collect and remain in the cisterna lamina terminalis.

The technique is as follows:

Once the interpeduncular cistern is filled, the patient's trunk is slowly pushed backwards, at the same time the head being extended so that the orbito-meatal line forms an angle of about 45 degrees with the horizontal plane. After keeping the patient in this position for about 20 seconds, he is made to sit slowly upright again, and the head flexed till the orbito-meatal line is parallel to the horizontal plane, in such a way as to allow the contrast medium to pass over the genu of the cistern of the corpus callosum, the axis of which is perpendicular to the horizontal plane. In some cases the cistern of the corpus callosum cannot be filled by this manoeuvre. We then try to make the gas enter it by the opposite opening, namely, via the posterior part. The contrast medium is collected in the cisterna vena magna Galeni where it comes via the ambient cisterns; the head is then extended in such a way as to fill the uppermost and the most anterior part of the cisterna vena magna Galeni which limits the inferior part of the splenium of the corpus callosum and which communicates with the cistern of the corpus callosum; this manoeuvre is naturally indispensable in those cases in which the contrast medium does not pass over the suprasellar cisterns.

The manoeuvre which we have just described is more or less identical with that used for filling the sulcus cinguli and the superior frontal gyrus.

To visualize the Sylvian fissure, which is even less frequently filled by the standard technique, we employ the following manoeuvre:

Having filled the prepeduncular cistern, the head is slightly extended (less than for the manoeuvre for the cistern of the corpus callosum), and at the same time flexed to the opposite side; the patient is kept in this position for about 20 seconds, allowing the contrast medium to accumulate in the deep part of the Sylvian fissure. After this, always keeping the head in the same degree of extension, the lateral inclination is increased in such a way that the contrast reaches the outer part of the fissure.

The head is then straightened once more and extended in such a way that the contrast medium ascends along the whole length of the oblique part of the Sylvian fissure.

Indirect localization. In order to localize structures which are not wholly in contact with the subarachnoid or ventricular spaces, it is necessary to use an indirect method. This consists of establishing the relations between certain structures, which it is possible to localize directly,

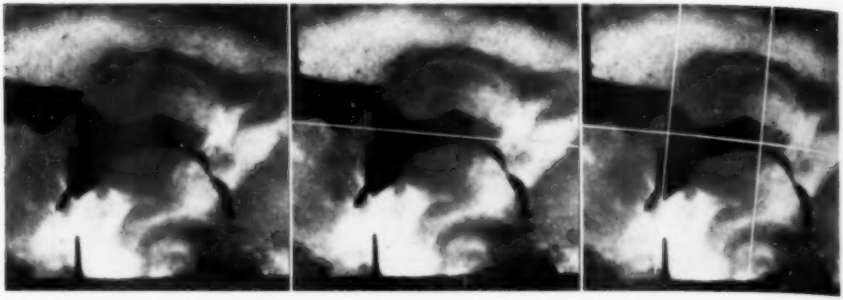


Fig. 12. Establishment of base line CA—CP (profile). Perfect visualization of anterior and posterior commissures with positive contrast medium.

and neighbouring structures which cannot be localized by direct roentgenography. The procedure necessarily involves the establishment of base lines. To be valid in stereotaxy a base line must satisfy two essential conditions:

1) it must be defined by structures which are roentgenographically constant and precise;

2) the relations which it bears to the structures which it assists in localizing must also be constant.

It is obvious that it would not have been possible to establish these base lines without numerous anatomic studies. These are still far from being completed and are being carried on at our hospital in collaboration with Dr. PIERRE TOURNOUX. We cannot enter into the details, but we think it is necessary to outline the principles.

We establish the projection of the base line on all the anatomic sections in the plane studied. This projection is made in a plane which is perpendicular to the sagittal and coronal planes of the brain for the sagittal sections, and in a plane parallel to the sagittal plane and perpendicular to the horizontal plane for the coronal sections. The sections are magnified according to the actual size of the various brains studied so that we possess a series of sections capable of being superimposed on the roentgenographic image. In practice, we use a special stereotaxic apparatus for the anatomic studies, which permits localizing needles to be introduced in the planes mentioned above. After serial section of the brain have been made, the marks made by the needles remain visible on the sections and make it possible to superimpose them exactly. If the position of a structure shown roentgenographically is reconstructed on the appropriate section, it is possible to project its situation on all the other sections which, we repeat, must be capable of being exactly superimposed (Fig. 13).

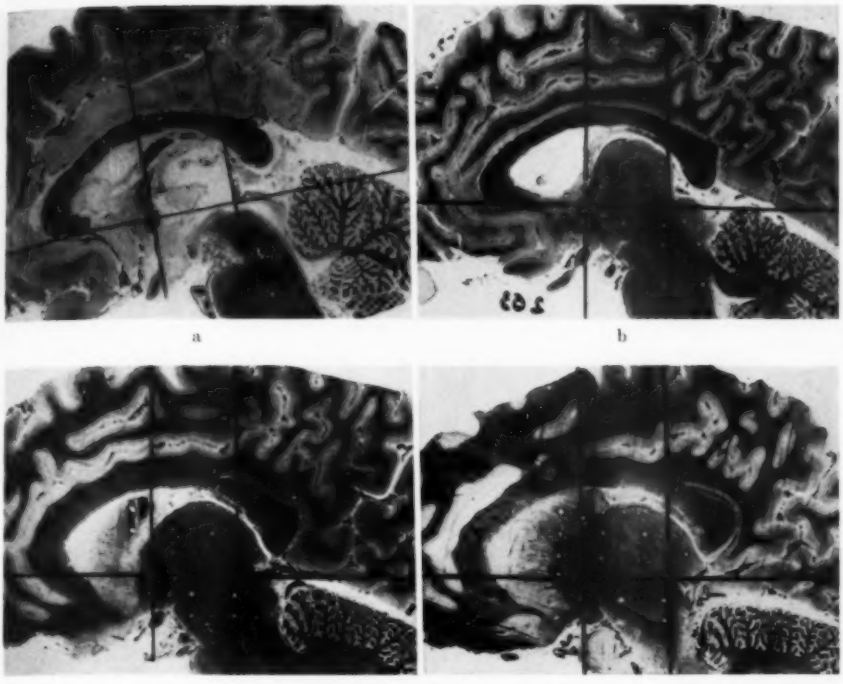


Fig. 13. Anatomic sections. a) base line CA—CP. Sagittal projections on sections passing through: b) red nucleus; c) medial portion of head of the caudate nucleus; d) medial nucleus.

The relations of a structure visible roentgenographically to those neighbouring structures which cannot be so shown thus become apparent (Figs. 13 and 14). Once the projection of the base line is established on the different sections, these are photographically enlarged to their actual size by using the markings of localizing needles in the brain, before its size is modified by the use of various fixatives and colouring agents.

Radiologic base line in the lateral view. Horizontal and vertical coordinates. For the thalamus, the sub-thalamic region, the infundibulum and the corpora striata, we use, in the lateral roentgenograms, a base line passing along the upper border of anterior commissure and the lower border of the posterior commissure (the CA—CP line, Figs. 12 and 13). Two perpendiculars to this line, one passing through the pos-

terior border of the posterior commissure, constitute the vertical coordinates. The base line itself forms the horizontal coordinate.

Great clarity of the contours of the anterior and the posterior commissures is essential (Fig. 12). We insist on the fact that even if for the posterior commissure a gaseous contrast medium may give a satisfactorily clear image, the use of a positive contrast agent is always advisable for the anterior commissure. In practice, in those cases in which this base line is sufficient for stereotaxic localization, and in which it is thus necessary to visualize only the anterior and posterior commissures, we utilise a positive contrast medium for both these structures. In general, 2.5 ml of Lipiodol injected directly into the anterior horn, and made to pass into the third ventricle, are sufficient.

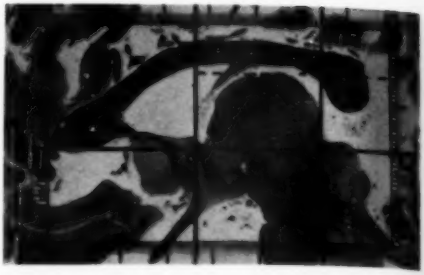


Fig. 14. Graduated anatomic sections with coordinates (lateral).

For the brain stem and cerebellum we establish a base line which allows for the variation of the angle made by the brain stem with the diencephalon. This base line is in a plane which passes through the upper part of the floor of the fourth ventricle and the lower part of the anterior wall of the Sylvian aqueduct. This defines the vertical coordinate. The perpendicular to this line, passing through the highest part of the roof of the fourth ventricle, constitutes the horizontal coordinate. The roentgenographic reconstructions are obviously made by the images of the fourth ventricle and the aqueduct.

Radiologic base line in the frontal projection. Sagittal coordinates. For the thalamus, sub-thalamic region, the infundibulum and the corpora striata, we use a base line which takes into account the variations which may occur in these structures, due to modifications in the ventricular system. This line, parallel to the median plane, passes through the superolateral border of the body of the lateral ventricle, which is seen in frontal views with the patient sitting, that is to say, it passes through the superolateral border of the highest part of the body of the lateral ventricle (Fig. 15).

For the brain stem and telencephalon, we make use of a median base line passing through the septum pellucidum. In the present state of our knowledge, it seems to us that this base line maintains constant relationships with the central grey matter in normal cases. The investigations we are carrying out with Dr. TOURNOUX tend to show the value of this line in pathologic conditions, notably in enlargement of the ven-

Fig. 15. Base line (frontal). Note clarity of contours of antero-inferior part of third ventricle with positive contrast medium.

tricular system. We insist on the fact that this vertical base line only defines a structure in relation to the sagittal plane and does not, in any way, help in determining its position as regards height; this is defined by the vertical coordinates of the radiologic base line in the lateral view.

The reliability of our technique

The procedure, the details of which we have described, has, in our opinion, a certain number of advantages which may be summarized by saying that it attempts to take into account all the possible kinds of variation in the individual structures. These variations should be noted not only in respect of the volume of the structures, but also in relation to their orientation within the cranial cavity. Moreover, the procedure attempts to reduce to a minimum the errors which may be made owing to the variations in the structures brought about by pathologic changes. We consider that an example may make this clear.

Anatomic definition of the thalamus by stereotaxy

The CA—CP base line in the lateral view gives the orientation of the thalamus, that is to say, it defines its inclination with respect to the stereotaxic frame. The perpendiculars to the base line passing through the anterior and posterior commissures delineate the length of the thalamus in its medial portion. (This length may vary, under normal conditions, by as much as 5 mm.) The length of the thalamus in its outer portion may be determined by the perpendicular passing through the anterior commissure and by the image of the upper part of the ambient cistern, which defines the postero-superior border of the pulvinar. (The length of the thalamus at this level may vary by more than 7 mm.) The height of the thalamus may be defined by the distance between the base line and the image of the anterior part of the sub-trigonal cistern which delineates the thalamus in its subarachnoid part. It may be surprising that we do not make use of the image of the floor of the body of the ventricle to define the upper limit of the thalamus; this structure, in our opinion, may in some cases be obscured by the choroid plexus and lead to errors.

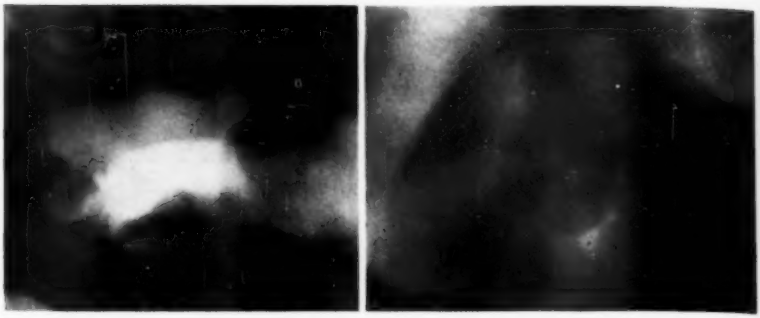


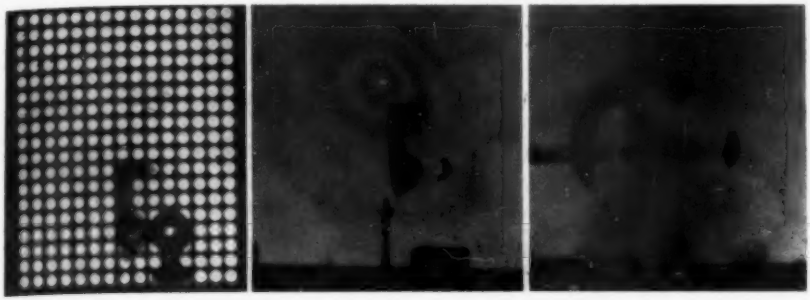
Fig. 16. Pinealoma. Ventriculography: filling defect of posterior part of third ventricle, more marked on the right side.

The relations between the base line in the frontal projection and the outer limits of the various portions of the thalamus being known, we can estimate the width of the thalamus by defining the relations between this base line and the lateral wall of the third ventricle and the ambient cistern, which constitute the medial limit of the thalamus. The measurements may thus be taken from the coordinates, the dimensions of which take into account the variations in size of the structures; as mentioned above, the height may vary up to 5 mm. The variations are even more important in pathologic conditions, whether localized to one structure, or affecting the whole hemisphere. In the course of our studies, we have tried to take note of the importance of the rôle played by these pathologic modifications in the stereotaxic localization of structures. An example of the difficulties arising is furnished by those cases in which there is ventricular dilatation without a tumour. Especially in cases with great dilatation of the third ventricle, one would expect the thalamus to be displaced laterally — and this is always the case. On the other hand, it seems that in certain cases the thalamus becomes smaller as if 'eroded' by the dilated ventricular cavity.

Having dwelt at some length upon the basic fundamentals we would emphasize that statistical anatomic studies, however exhaustive and rigorous they may be, will not be enough for radiologic investigations in stereotaxy. The great variations, in every sense, of normal and pathologic structures of the nervous system makes it necessary for the localization to be made individually in each case.

Application of the stereotaxic method to the treatment of brain tumours

In a paper which appeared in the 'British Journal of Radiology', in collaboration with J. ABOULKER, we have described the technique in



a b c

Fig. 17. Same case as in fig. 16. Implantation of radioactive gold: a) localization with the double grill; b) and c) radioactive gold implanted in the tumour.

detail and also reported the preliminary results of the treatment by the implantation of radio-active gold by stereotaxy of certain tumours judged inoperable by the usual surgical procedures.

We shall not refer to the clinical and surgical problems of this treatment, which may still be considered to be in an experimental stage. We shall confine ourselves to emphasizing its purely radiologic aspects. The possibility of treating certain brain tumours by the implantation of radio-active particles in situ presents two considerations to the radiologist: the question of diagnosis, and his participation in the therapeutic procedure. When a stereotaxic operation is considered, the diagnostic problem is different from the one which arises when it is only a matter of an operative flap; in the latter case, a topographic diagnosis is usually sufficient, whereas in the case of a stereotaxic operation, it is necessary to localize the lesion much more precisely. As a matter of fact, it is essential to know not only the site of the lesion, but its size and relation to neighbouring structures. This knowledge may prove of primary importance in rendering the stereotaxic operation possible. A diagnosis of the histologic nature of the tumour is also important as this may furnish an indication or contra-indication of the method. Certain facts regarding the tumour — whether it is vascular or not, and whether it is cystic, infiltrating, etc. — should be determined. These will not only govern the therapeutic indications but also influence certain elements of the surgical technique. It is for all these reasons that when one has a stereotaxic operation in view, it is rarely that only one type of special radiologic examination will suffice.

As regards the therapeutic procedure itself, the presence of the radiologist is essential. He will be responsible for obtaining the images of the ventricular system or the cisterns to be used to localize the point where the radio-active particle (preferably in the centre of the tumour) is to

Fig. 18. Brain stem tumour with indentations in the posterior lower part of third ventricle; irregular compression of aqueduct and a slight dislocation of fourth ventricle backwards. *Top left:* ventriculography with positive contrast medium. *Top right:* localization with the double grill. *Below:* radioactive gold placed in the tumour, probably in the right cerebral peduncle.

be implanted. A gaseous contrast having been shown to be insufficient in certain cases, it is necessary for the radiologist to be experienced in the use of a positive heavy contrast medium. In the cases of the stereotaxic implantation of radio-active particles, positive contrast medium will not, owing to the limitation of movement imposed by the stereotaxic conditions themselves, replace air, but be complementary to it. A positive contrast medium is sometimes necessary to define sharply the borders of the lesion, and sharpness is essential for the stereotaxic procedure and cannot always be achieved by air.

The guidance of the radiologist will be necessary for the interpretation of the films and in the decision regarding the surgical approach. It is difficult to apportion at the present time the particular work of each member of the stereotaxic team.

In the case of pituitary tumours, we make use of another stereotaxic technique to reach the tumour through the nose. Special stereotaxic apparatus described by TALAIRACH and TOURNOUX is employed. Radiologic control during the procedure is also essential, as in the other complementary examinations, such as fractional encephalography, pre-operatively to define the tumour, and later to gauge the results of treatment.

In conclusion we would say that it is certain that these new therapeutic procedures justify the efforts made so far by neuroradiologists who have always thought it useful to try to make diagnostic radiology as precise as possible, in spite of the fact that the exact site of the tumour and its histologic nature have not been considered essential in the majority of the usual neurosurgical procedures. Radiology assumes a great importance in stereotaxy because it is an integral part of the surgical procedure, each step of which it controls. The procedures require radiologico-anatomic studies with a view to determining on the one hand the anatomy in the living, and on the other, to perfecting our general knowledge of the brain. As a matter of fact, as LINDGREN has recently said, the anatomy of the ventricular system is thoroughly known, but our knowledge of the subarachnoid spaces still requires to be perfected. The collaboration of the neuroradiologist, neurosurgeon, and neuroanatomist in stereotaxic investigations is the ideal ground for the study of the subarachnoid spaces and their normal and pathologic variations.

SUMMARY

The authors describe the roentgenologic procedures which permit stereotaxic measurements. As localizations made from ordinary roentgenologic examinations are not sufficiently accurate for the study of the majority of intra-cranial structures, the help of contrast media and stereotaxic base lines are necessary. Some examples are given.

ZUSAMMENFASSUNG

Die Verfasser beschreiben die röntgenologischen Prozeduren, welche die Ausführung stereotaktischer Messungen zulassen. Für das Studium der meisten intrakraniellen Strukturen sind die mit Hilfe von gewöhnlichen Röntgenaufnahmen gefundenen Lokalisationen nicht genügend exakt; daher ist die Anwendung von Kontrastmitteln und stereotaktischen Referenzlinien notwendig. Illustrative Beispiele werden gegeben.

RÉSUMÉ

Les auteurs décrivent les techniques radiologiques qui permettent des mesures stéréotaxiques. Étant donné que les localisations faites à partir d'examens radiologiques ordinaires ne sont pas assez exactes pour l'étude de la plupart des structures intracraniennes, il est nécessaire d'utiliser des moyens de contraste et les lignes de base stéréotaxiques. Des exemples sont donnés.

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VISUALIZATION AND TREATMENT OF CYSTIC BRAIN TUMORS BY STEREO-ENCEPHALOTOMY

by

F. Murtagh, H. T. Wycis, R. Robbins, M. Spiegel-Adolf, and *E. A. Spiegel*

One of the applications of stereo-encephalotomy originally suggested by SPIEGEL, WYCIS, MARKS and LEE in 1947 was the use of the stereo-encephalotome in the treatment of subcortical tumors.

Cystic tumors are particularly suited to management by stereo-encephalotomy since, by this means, a needle or cannula may be accurately directed into the cyst cavity through a small trephine opening. This may be useful in two ways. First, as a diagnostic procedure it may establish the presence of a cystic lesion as opposed to a solid one, if preliminary roentgen studies have suggested the presence of a tumor. Cyst fluid may be obtained by aspiration and the identity of the tumor may be established from the fluid, as in the case of craniopharyngioma. (Enzymatic studies (SPIEGEL-ADOLF) particularly seem to be of interest.) In addition, a radiopaque substance may be placed in the cyst and its size determined by roentgenograms. Secondly, such a puncture may serve for therapeutic procedures. The cyst may be evacuated of its contents to provide decompression, and/or therapeutically active substances may be introduced into the cyst. A rather favorable situation for the injection of radioactive substances exists in the case of cystic tumors since it would seem that the agent injected could at least act upon that portion of the tumor that forms part of the wall of the cyst. We have attempted to apply this method in the following cases.

Case 1. 12-year-old boy had experienced headaches almost daily for 10 years. On occasion the headaches were severe and he frequently vomited. On the day of admission the headache had been severe, vomiting had occurred and had been attended by a generalized convulsion.

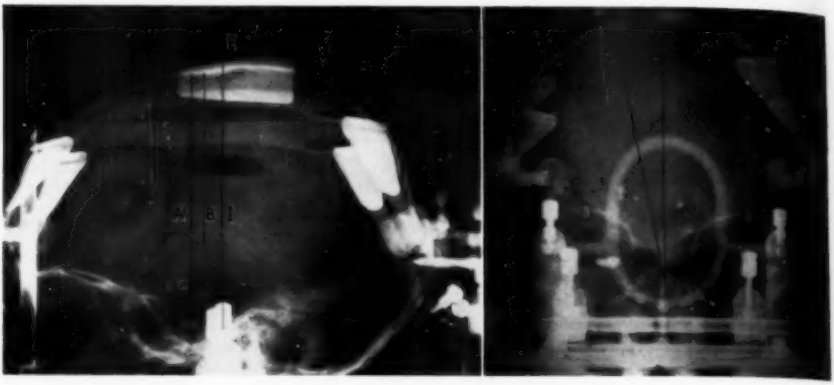

Fig. 1. Case 1. Roentgenogram of the skull with the stereoencephalotome in position. *Left:* Lateral view. E = electrode; I = interaural line. Lines A and B reach the calcification at *a* and *b* respectively. *Right:* A. p. view. E = electrode in midsagittal plane. P = puncture line at an angle of 10° in the median plane.

On admission he was in a drowsy, post-ictal state but was soon easily aroused. The neurologic examination was negative except for sluggishly reacting pupils and generalized depression of the deep tendon reflexes. Ophthalmologic examination revealed early papilledema and bitemporal field defects for red color.

Conventional roentgenograms of the skull demonstrated suprasellar calcification and demineralization of the dorsum sella compatible with the diagnosis of a craniopharyngioma. Air study demonstrated symmetrical internal hydrocephalus and a large tumor mass in the region of the third ventricle.

It seemed that this tumor, which encroached upon large areas of the brain stem and hypothalamus could hardly be totally removed without great risk to the patient. It occurred to us, that, if the tumor was cystic it might be successfully tapped and aspirated with a hollow needle, directed by the stereo-encephalotome, and that the same approach could be used for the injection of radioactive substances.

On 9 March 1953, the cyst was punctured through a trephine opening at the vertex of the skull by means of a hollow needle directed by the stereo-encephalotome to the approximate center of the area indicated by calcification. Five (5) ml of yellow fluid were aspirated and replaced with 3 ml of pantopaque mixed with methylene blue and an iodine tracer substance in order to ascertain whether the method of injection of radioactive substance was safe without leakage (Fig. 1).

A post-operative roentgen examination of the skull demonstrated the pantopaque to be distributed on either side of the midline and in the right temporal horn. Apparently due to the fact that the cannula had multiple openings in its lower part, much of the oil had spread around the tumor mass.

There was no change in the edema of the optic nerve heads but the visual fields charted on 16 March showed a recession of the bitemporal cut for color.

He was discharged on 18 March, but was readmitted on 11 April because of headaches, nausea and vomiting. There were two diopters of papilledema in the right eye and one diopter in the left eye. The bitemporal field defect for red color was still present.

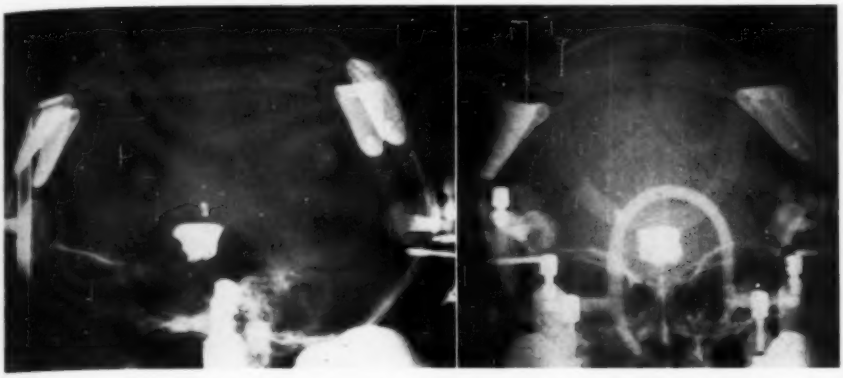

Fig. 2. Case 1. Cystic cavity filled with pantopaque. *Left:* Lateral view. *Right:* A. p. view.

On 23 April, the cyst was punctured again using the stereotaxic technique. Since the cyst appeared to be more on the right side, the puncture was made 21 mm lateral on the right with the needle inclined 10° medialwards in the frontal plane. Five (5) ml of golden yellow fluid were aspirated and 3 ml of pantopaque introduced into the cavity. Post-operative roentgen examination of the skull showed pantopaque collected in the cavity (Fig. 2).

On 28 April, there were 3 diopters of choked disc in the right eye and 2 diopters in the left eye.

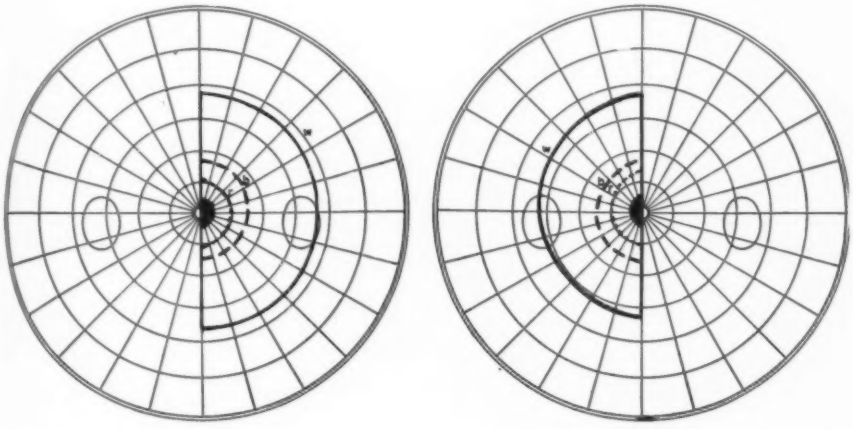

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Fig. 3. Case 1. Visual fields for white and red before injection of P^{32}. Test objects 2/1,000 w. r. b.

Fig. 4. Case 1. Roentgenogram of skull, lateral view. Note metal tip of retained catheter situated in the cyst cavity.

Application for radioactive colloidal phosphate was made to the Atomic Energy Commission and this substance was received on 18 August 1953. At that time the patient was complaining of recurrent headaches with vomiting. Perimetric fields showed complete, bitemporal hemianopsia with some peripheral contraction particularly in the left eye. There was splitting of both maculae. Three diopters of papilledema were present in both eyes (Fig. 3).

On 24 August 1953, by means of the stereotaxic method, the cyst was again punctured; 11 ml of milky-white fluid were aspirated and 1.1 mc of P^{32} in the form of colloidal chromic phosphate injected in a fluid volume of 9 ml.

The post-operative phase was uneventful. Headache subsided within a week and at the end of two weeks the papilledema subsided completely. Perimetry showed bitemporal hemianopsia of the central fields of vision. Field studies done at six months showed marked improvement.

The boy was symptomfree for 17 months at which time he developed generalized weakness, had recurrent headaches and difficulty with vision. Visual fields demonstrated large bitemporal scotomata but no visible papilledema.

On 4 March 1955, the cyst was again punctured using the stereotaxic instrument. A polyethylene tube was placed in the cyst cavity through a cannula and the cannula removed leaving the tube in place. Five (5) ml of golden yellow fluid were removed and replaced with 0.5 mc P^{32} in the form of colloidal chromic phosphate in a fluid volume of 4.5 ml. The polyethylene tube was subsequently plugged and its end buried in the corner of the wound where it may be used at any future time for drainage of the cyst and further instillation of therapeutic substances (Fig. 4).

The boy improved following this procedure; headaches, and weakness had disappeared. Visual fields on 15 August 1955 show diminution in size of the scotomata (Fig. 5).

A more recent examination, April 1956, shows that visual fields are still improved and the patient is symptomfree.

Case 2. 40-year-old female had been seen in the clinic at Temple University School of Medicine since 1947 because of obesity, uterine fibroids and repeated episodes of pyelonephritis. A hysterectomy was performed in 1948. The first mention of headache was in 1949 when she complained of mild bitemporal and occipital headache which was controlled by aspirin.

She was admitted to the hospital on 21 March 1955 with nephrolithiasis. During this admission the presence of diabetes mellitus was established. She had been having bitemporal headache for several weeks prior to admission. Pre-operative studies, however, were negative for suspected intra-cranial lesion. Eye ground evaluation had noted the presence of fullness of the optic discs, but no frank papilledema.

A pyelolithotomy was performed on 31 March 1955 without incident. Post-operatively, she appeared moderately stuporous and slow in response. Examination revealed the

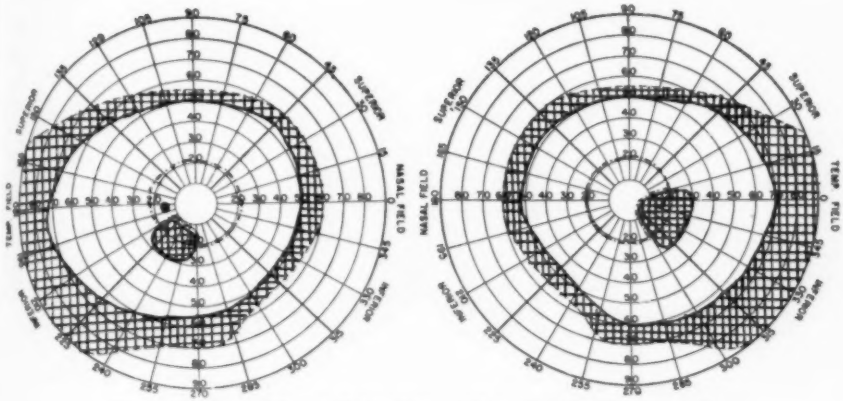

Fig. 5. Case 1. Visual fields 24 months after injection of P^{32}.

presence of three diopters of papilledema in the right eye and four diopters in the left eye. Careful lumbar puncture disclosed a spinal fluid pressure of 450 mm H_2O and clear, colorless fluid. Roentgen examination of the skull disclosed an enlarged pituitary fossa with demineralization and erosion of the floor of the sella, thought to be due to the presence of a tumor in the pituitary region.

Visual fields demonstrated enlargement of the blind spot bilaterally and a bilateral, central, relative, inferior, altitudinal anopsia to red only (Fig. 6).

It was our feeling that it would be of great importance to know if this lesion was cystic; if so, it could be treated according to the methods already described.

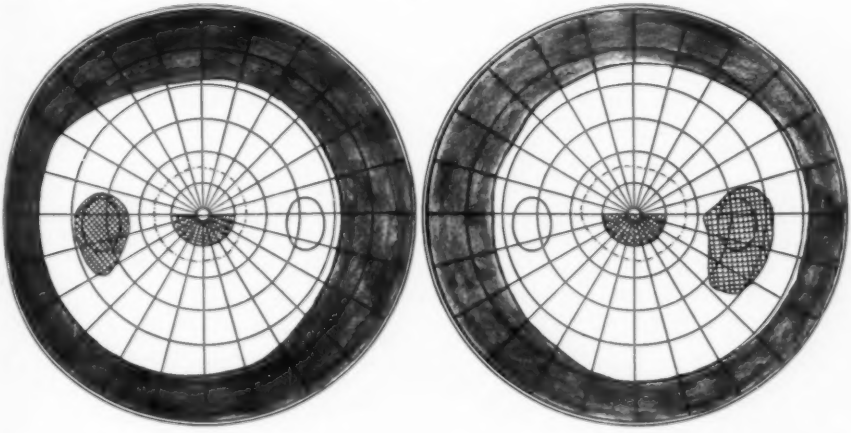

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Fig. 6. Case 2. Visual fields pre-operatively. Note inferior anopsia to red color. Test objects V = 6/6, 2/1,000 W, 3/1,000 R.

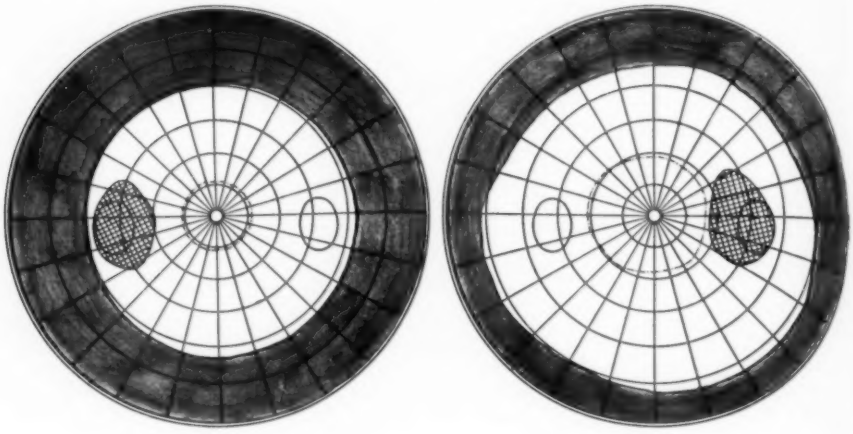

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Fig. 7. Case 2. Visual fields, four months after injection of P^{32} into cyst. Test objects V = 6/6, 2/1,000 W, 3/1,000 R.

Thus, on 14 April 1955, using the stereo-encephalotome, a hollow needle was inserted into the region of the tumor through a trephine opening in the vertex. A cyst was encountered and 8 ml of blood-tinged xanthochromic fluid were obtained. 0.88 mc of P^{32} in the form of colloidal chromic phosphate were instilled into the cyst in a 8.0 ml volume. A polyethylene tube was left in place in the cyst and the end buried in the scalp. Postoperatively there was some leakage of radioactive substance around the tube.

Post-operatively the patient did well. The choked discs gradually subsided and within four weeks had completely resolved. On 21 July 1955, the patient was symptom-free and there was no papilledema. Field examination revealed that the relative inferior altitudinal anopsia had disappeared (Fig. 7).

Conclusions

The progressive course of expanding suprasellar lesions, particularly craniopharyngiomas, necessitates the consideration of operative treatment. However, CUSHING's statement that craniopharyngiomas offer the most baffling problem which confronts the neurosurgeon, still holds true. To give only a few examples. In the series of craniopharyngiomas reported by BECKMAN and KUBIE one finds that of 19 cases operated upon by Sir PERCY SARGENT (mostly only aspiration of the cyst), 13 died (68 %). Cushing's statistics in 87 cases is much better (21.8 % case mortality, 14.6 % operative mortality) but still rather high. It has not been improved by more recent authors except for LOVE et coll., who performed partial removal in 11 cases without fatality but mention the further course in some instances only. GRANT reports a case mortality

of 35 % and an operative mortality of 25 % and INGRAHAM and SCOTT, who included cases that survived the operation for some time, had a survival rate of only 31 % (69 % mortality). The latter authors suggest roentgen therapy; however, GRANT as well as BUCY found this method of treatment disappointing. Bucy further states, that Scarff's method of making a defect in the dome of the cyst so that it drains into the ventricular system gave in his hands no better results than evacuating the cyst. In SCARFF's own series 2 out of 7 patients died (28 %). In spite of the more recent reports by INGRAHAM, MATSON, MCLAURIN, and others, of marked reduction in operative mortality with the pre- and post-operative use of cortisone and ACTH, the total removal of these lesions remains a formidable operative procedure.

CUSHING stated in 1932: "Until some method is devised whereby the usually multiocular epithelial lesions can be destroyed or inactivated *in situ*, the mortality will remain high."

We cannot claim, as yet, that the ideal method of treatment has been found since we were able to introduce a radioactive substance by the stereotaxic method in only two cases which have been followed post-operatively for two years and for ten months, respectively. However, it seems permissible to infer from our study, at least, that the stereotaxic method greatly facilitates and increases the accuracy of punctures of cystic tumors for diagnostic and therapeutic purposes. If necessary, such punctures can be carried out repeatedly without undue hazard to the patient. The introduction of a polyethylene catheter into the cyst and leaving it *in situ* obviates even the necessity of repeated punctures.

In the cases presented, the progressive course of the disease, indicated by papilledema and shrinking of the visual fields, could be stopped and a definite improvement in the general condition of the patient and in the ophthalmologic findings could be obtained.

SUMMARY

Cystic tumors are particularly suited to stereo-encephalotomy since a needle or cannula may be directed into the cyst cavity through a small trephine opening, either for diagnosis or for therapeutic procedures. The method has been applied in two cases. Both patients had suspected tumors in the pituitary region. P^{32} in the form of colloidal chromic phosphate was injected into the cyst cavity. Both patients responded well with alleviation of symptoms of headache, papilledema and visual field defects. One case has been followed for two years, the second for 10 months.

ZUSAMMENFASSUNG

Zystische Tumoren sind für die Stereoencephalotomie besonders geeignet, da eine Nadel oder eine Kanüle durch eine kleine Trephinenöffnung hindurch in den zystischen Hohlraum eingeführt werden kann; dieses kann zu diagnostischen oder therapeutischen Zwecken geschehen. Die Methode ist in 2 Fällen benutzt worden. Bei beiden Patienten lag ein Verdacht auf einen Tumor in der Hypophysengegend vor. P^{32} in der Form von kolloidalem Chromphosphat wurde in den Zystenhohlraum injiziert. Beide Patienten reagierten gut hierauf und zeigten eine Linderung der Kopfschmerzen, eine Abnahme des Papillenödemes und eine Verringerung der Gesichtsfeldeinschränkungen. Der eine Fall ist 24 Monate lang beachtet worden, der zweite Fall 10 Monate lang.

RÉSUMÉ

Les tumeurs kystiques se prêtent particulièrement bien à la stéréo-encéphalotomie, car on peut introduire directement dans la cavité kystique une aiguille ou un trocart par un petit trou de trépan, à des fins diagnostiques ou thérapeutiques. Cette méthode a été appliquée dans deux cas. Les deux malades étaient suspects de tumeur dans la région hypophysaire. Du P^{32} sous forme de phosphate de chrome colloïdal fut injecté dans la cavité du kyste. Les deux malades ont bien réagi et ont présenté une amélioration de leurs symptômes de céphalée, d'oedème papillaire et d'altérations du champ visuel. Un cas a été suivi pendant 24 mois et le second pendant 10 mois.

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RADIOACTIVE ISOTOPES IN THE LOCALISATION OF BRAIN TUMOURS

by

S. Kramer[1], *L. K. Burton* and *N. G. Trott*

The possibility of using radioactive isotopes for the localisation of brain tumours has been widely investigated (MOORE, KOHL, MARVIN, WANG and CAUDILL 1950), (ASHKENAZY, DAVIS and MARTIN 1951). It was hoped that isotope encephalography would become the diagnostic method of choice since, unlike ventriculography and arteriography, there is no mortality and practically no discomfort to the patient.

At the Royal Marsden Hospital, in collaboration with Mr. WYLIE MCKISSOCK at the Atkinson Morley Hospital, extensive clinical trials have been made over the past four years of radioactive localisation methods: by external counting using I^{131} diiodofluorescein (BELCHER, EVANS and DE WINTER 1952); for *in situ* measurements, the study of P^{32} (STAPLETON, MCKISSOCK and FARRAN 1952).

In this report some of the general problems of external localisation are first discussed, and an account is then given of recent clinical work at these hospitals using K^{42}.

General problems. Various radioactive labelled substances, particularly:

a) I^{131} diiodofluorescein and I^{131} human serum albumin, and

b) P^{32}, K^{42}, As^{74} and I^{131} as inorganic ions, have been tested for this type of investigation. Physical properties of these isotopes are shown in Table 1.

[1] Dr. S. KRAMER is now Associate Professor of Radiology, Jefferson Medical College of Philadelphia, U. S. A.

Table 1

Radioactive isotopes used in brain tumour localisation

Isotope	Half-life	β Energy Max. meV	γ Energy Mean meV	Chemical Form	Remarks
P^{32}	14.3 days	1.7	—	Phosphate	No γ rays. Suitable only for in situ measurements.
K^{42}	12.4 hours	3.6	1.5	Carbonate	
As^{74}	19 days	1.5	0.6	Arsenate	~ 28 % positrons.
I^{131}	8.0 days	0.6	0.4	Iodide; Diiodofluorescein; Iodinated human serum albumin	

Measurements made here of the uptake in tissue specimens obtained at operation show that for P^{32} and K^{42} the specific activity in cerebral tissue is about 1/5th of the average for the whole body. However, with very few exceptions, the specific activity in tumour always exceeds that of normal brain, or of blood.

In clinical investigations, the quantity of radioactive material that can be used is limited by the possible radiation hazard to the patient. However, without exceeding a reasonable whole body dose of about 1 rad, it is possible by using sensitive directional scintillation counters, to survey the radiation from the brain, and to locate a region of abnormally high activity. The efficiency of such counters, for quanta falling on the crystal, may approach 100 %.

In the simplest terms, one is trying to detect a region (the tumour) of volume v, radioactive concentration s, within a total volume (the skull) V, having a radioactive concentration S, where $S < s$. S is the specific activity, defined as the number of microcuries per gram of tissue. The accuracy of detection and localisation will therefore depend upon:

a) the specific activities and their ratio s/S (s/S may conveniently be termed the "uptake ratio");

b) the volume of the tumour, v, and its distance from the detector;

c) the background counting rate of the detector and also the dimensions of the aperture of the collimator that may be used to screen the crystal from all but a relatively narrow cone of radiation.

In analysing this problem by calculation and by laboratory experiment, one tries to formulate minimum requirements for successful clinical work. Unfortunately, whilst in the summary just given there are already several variables, such conditions are highly artificial; in particular, both tumour and normal brain will in fact show variations in specific activity. At this hospital, BELCHER and EVANS (1951) made experi-

ments with a scintillation counter, using a skull containing a uniform distribution of I^{131}, with inclusions of higher specific activity; the present authors have made similar experiments with K^{42}. BELCHER and EVANS used a lead collimator of wide angle. For the experiments, and later clinical work, with K^{42}, the counter was as shown in Fig. 1; the heavy collimator was necessary for work with the 1.5 meV gamma rays from this isotope.

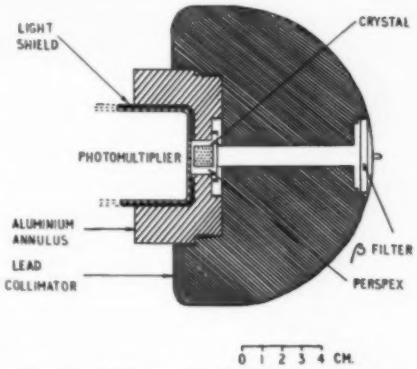


Fig. 1. Collimated scintillation counter for use with K^{42}.

The specific activities of the solutions used in the experiments were comparable with those that are obtained in patients to whom an acceptable dose of the isotope has been given. At the counting rates obtained in the experiments (about 10 to 30 counts/sec for background and for a uniform distribution of the isotope) a change of 20 % was the least that could be detected with certainty. Now the effect produced on the counting rate by a particular inclusion will depend very much on its shape and distance from the counter; consequently, it is not possible to deduce in general, from the sensitivity of the counter, the least size and specific activity for any detectable inclusion. For short cylindrical inclusions comparable results have, however, been obtained by BELCHER and EVANS, and by the present authors. For example, to detect cylindrical 5 ml inclusions the specific activity of the inclusion relative to that of the surrounding medium must be about 30. It can also be shown that, provided the whole inclusion is within the cone defined by the aperture of the collimator, the relative specific activity for a detectable inclusion will be approximately inversely proportional to its volume. If the tumour were widely diffused, however, the relative specific activity in tumour tissue required for successful detection would be still higher than these results indicate.

For detection it is only necessary to observe that the counting rate shows an unusual variation from normal when the counter is moved through a particular series of positions. To apply this information, and determine the *position* of the inclusion is more difficult. Various techniques have been developed. The earlier workers used shielded, but uncollimated detectors, set at a number of positions on the skull (upper diagram, Fig. 2). In principle, the counting rate will vary inversely as the square of the distance of the concentrating region from the detector, so that one should be able to determine, by counting at symmetrical

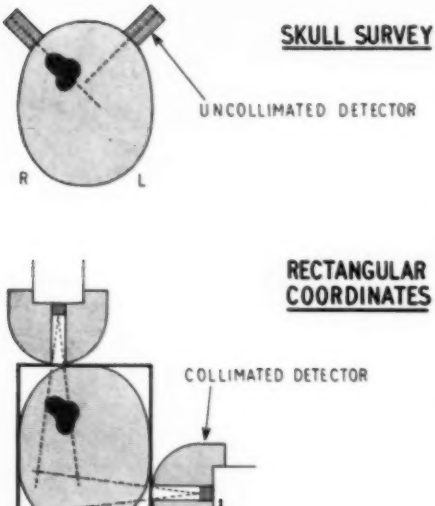


Fig. 2. Surveying procedures in the localisation of brain tumours by external counting.

positions, the side at which the concentration occurs. In an alternative method, a collimated counter is moved along rectangular co-ordinates (lower diagram, Fig. 2), surveying the skull from two perpendicular planes. In the laboratory, some precision can be obtained by the use of this technique, as can be inferred from the curves shown in Fig. 3.

It will be clear that, for localisation, more information is required than for detection alone, and that error in localisation will almost certainly arise, if one is already working at the limits of detection. Unfortunately, investigations with the substances so far tested, show that specific activity ratios tumour/normal are usually between 5 and 30; it follows that, with the techniques described, detection itself will often prove difficult. Radioactive methods, using simple counting techniques, have, it may be pointed out, proved successful in the different problem of detecting functioning thyroid metastases because the concentration relative to that of surrounding tissue may then be of the order of 1,000.

A new and elegant method of detection and localisation was devised by Brownell and Sweet (1953). This depends on the use of positron emitters, like As^{74}, and coincidence counting techniques. The method appears to have definite advantages over those used hitherto.

Clinical investigations using K^{42}. It was evident that, except for high (in the range 10—30 : 1) uptake ratios, there was no possibility of successful external localisation. In contrast to published work from some other centres, Belcher, Evans and De Winter (1952) were unable to achieve successful localisation, using I^{131} diiodofluorescein, by scintillation counting methods. Work with the simple metabolite K^{42} was first described by Selverstone, Sweet and Ireton in 1951, in which year we commenced investigations with this isotope, using the simplified scintillation counters (Fig. 1) then available commercially. Following preliminary external counting surveys study was made of specimens obtained at operation. (McKissock took an active part in this work, earlier, in collaboration with Stapleton, and Farran, later with the present

authors and CLARK.) Over a period of twelve months 113 patients were given intravenous or oral doses of K^{42}, either $^1/_2$ to 3 hours, or 18 to 24 hours, before operation. Pieces of tumour and normal brain where possible were obtained from 57 patients, and assayed by liquid counters. If normal brain was unobtainable a blood sample was taken. The results are summarised in Diagram 1.

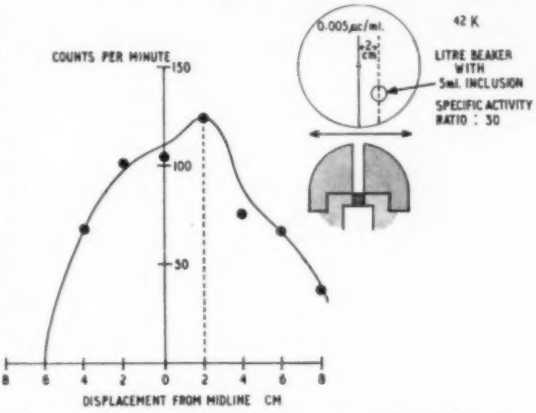


Fig. 3. Detection of an inclusion by rectangular survey with a collimated scintillation counter. The specific activity of the inclusion is 30 times that of the surrounding solution.

Higher uptake ratios were found for the group given the dose intravenously; the specific activity of normal brain tissue was, in only 6 out of 57 cases, greater than one-half of the average specific activity, and was always less than the specific activity of blood. The tumour concentration varied rather widely from patient to patient. This may be partly due to the difficulties of counting the low activities present. On the other hand, the concentration of radioactive potassium depended to some extent on the nature of the tumour specimens submitted. Where solid tumour was encountered at operation, such as was the case with glioma, grade I and II, or with a neurilemmoma, the specimen would consist of uniform tumour tissue. But where the tumour was soft and semi-fluid, with haemorrhage and necrosis in evidence, as is found so commonly in the highly malignant gliomata, then the tumour specimen was often inseparably mixed with blood and amorphous necrotic material, which of course greatly altered the specific activity of the sample tested. *In vivo* measurements which

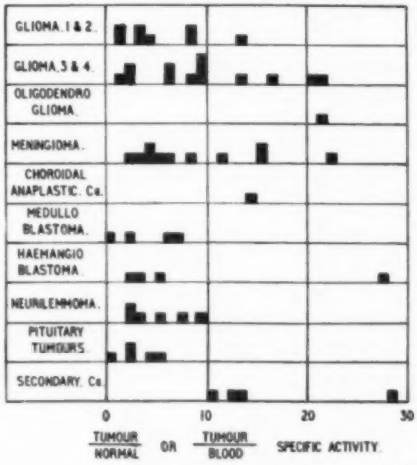
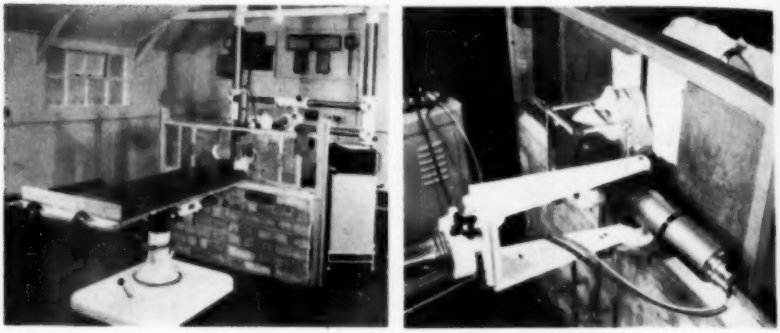


Diagram 1. Results of measurements of the specific activity of specimens of tumour obtained at operation on 57 patients, following the administration of K^{42}.



a b

Fig. 4. a) General view of equipment used for external surveys, following administration of K^{42}. b) Collimated counter in position, showing grid used for the rectangular surveys. The lead walls are in position.

were made with a 3 mm diameter needle Geiger counter at operation on some 15 patients confirmed the results found by assay of specimens.

Whilst a number of tumour specimens, showing high uptake ratios, (20—30 : 1) were found, it was clear that only very careful external measurement could give successful external localisation. A building was erected and equipped for such investigations at the Atkinson Morley Hospital. The apparatus is illustrated in Fig. 4. The detecting system comprised a scintillation counter (Type N 509) with high energy collimator, and a ratemeter (Type 1037). To prevent as much stray radiation as possible from reaching the counter, due to K^{42} distributed in the patient's trunk, a pair of vertical sliding lead doors was used. As clinical work proceeded, some improvements were made in the counting system, the size of the crystal being increased, and the collimator modified. As will be seen, tumours could be detected with moderate success by this method, but accurate localisation was more difficult. The lead doors were only partially successful in screening the counter from the patient's trunk, whilst they made the movement of the counter less flexible. In general, two lateral surveys and one superior were made for each patient. As has been discussed above, from these surveys one should be able both to detect and localise a tumour which concentrates the isotope. The superior survey, however, was usually difficult to interpret since in this position the counter aperture was exposed to part of the trunk.

For the radioactive surveys, the quantity of K^{42} given to the patient was limited to 1 mc and for intravenous injection, the carrier content was limited to 80 mg potassium. The average absorbed soft tissue radiation dose was about 1 rad. No clinical information was given to those making

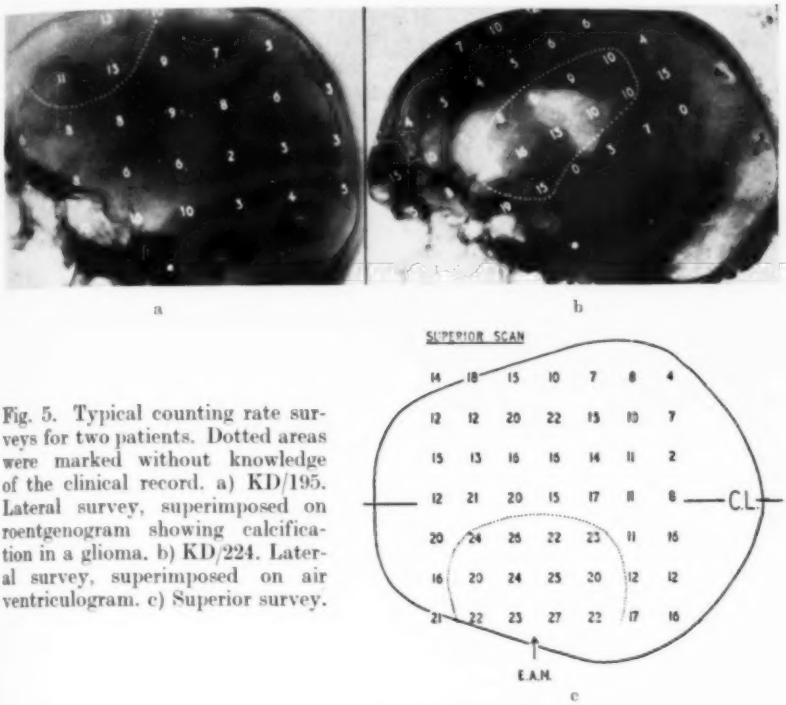


Fig. 5. Typical counting rate surveys for two patients. Dotted areas were marked without knowledge of the clinical record. a) KD/195. Lateral survey, superimposed on roentgenogram showing calcification in a glioma. b) KD/224. Lateral survey, superimposed on air ventriculogram. c) Superior survey.

the radioactive surveys until their results had been reported; however, investigations were restricted to supra-tentorial lesions, as it was felt that any useful results would be precluded in the posterior fossa by the presence of the neck muscle masses. As a result of preliminary measurements of the variation of uptake with time, the surveys were made commencing 15 minutes after intravenous injections, or 90 minutes after an oral dose had been given.

Typical surveys, superimposed on roentgenograms, are shown in Fig. 5.

The results for 80 patients are summarised in Table 2; they will be presented in more detail elsewhere.

It will be clear that the method is only moderately successful; indeed, if one considers this whole group of patients, the result of the test has apparently been correct in rather less than 60 % of the investigations. DUNBAR and RAY (1954) using I^{131} human serum albumin, and also making their report without the clinical record, obtained comparable results.

Some errors can no doubt be attributed to insufficient relative concentration of the isotope in the tumour. However, the large group for

Table 2

Results of external surveys on patients, following administration of K^{42}

a. *Tumour verified surgically, or by radiographic or other methods*

Result of isotope survey	Surgically* verified (36 patients)	Not surgically verified (7 patients)
Correct localisation	61 %	85 %
Correct site, wrong side	30 %	15 %
Tumour not diagnosed	9 %	—

* 23 of the 36 surgically verified tumours were gliomata, the remainder being of various histologic types. The percentages of gliomata in each of the three groups were identical with those given for the whole 36 tumours.

b. *No tumour found on surgical examination, or suspected at present from other tests*

Result of isotope survey	Surgically verified (5 patients)	Not surgically verified (32 patients)
No tumour diagnosed	80 %	44 %
Tumour diagnosed	20 %	56 %*

* 16 of the 18 patients for whom the isotope diagnosis of brain tumour is believed to be incorrect, are still sub judice.

whom the side was incorrectly diagnosed require some discussion. The difficulty in interpreting the superior scans has already been mentioned; in consequence, for determining the side, reliance was placed on the difference of counting rate in the two lateral surveys obtained with the collimated counter. This may be misleading for two reasons. Firstly, if the whole outer surface of a tumour is metabolising K^{42}, whilst the centre is necrosed, a collimated counter may detect the tumour more readily when at a distance from it. Secondly, clinical experience has taught us that a cerebral tumour is often not confined to one hemisphere, and that while the bulk of the tumour might be on one side of the falx, (and this large space-occupying lesion shown by radiographic means and confirmed at operation), yet a smaller but more actively growing part of the tumour might have crossed the midline, and because of its higher cellular activity, show up in the radioactive scan. The former, though not the latter difficulty could possibly have been removed by repeating the lateral surveys with an uncollimated counter; for such extensive work, however, a method of automatic scanning would have been essential.

Conclusions

The clinical results we have obtained up to the present, using K^{42}, may be summarised as follows. For a rather high proportion of patients, the side at which a tumour occurred was incorrectly determined; in addition, for a large group of patients, our report that a tumour was present

was probably incorrect. In consequence, the results obtained with our equipment in its present form are likely to influence the final diagnosis for only a limited number of patients. A similar conclusion was reached by SJÖGREN (1953) following his work using I^{131} diiodofluorescein. To some extent, of course, and this may remain a problem however good the physical technique, some of our difficulties have arisen because the tumour uptake is apparently so variable. This must necessarily make us hesitate to undertake the development of more elaborate, probably automatic recording apparatus. We have, of course, at this hospital, considerable experience in the development of fast scanning instruments for the localisation of I^{131} in the diagnosis of thyroid disorders (MAYNEORD, EVANS and NEWBERY 1955), and are naturally tempted to use that experience for brain tumour investigations. Necessarily, because of the effort involved, we are cautious. Yet, from the positive results we have obtained up to the present, we may reasonably conclude that with some technical improvement radioactive localisation will be added to the diagnostic methods routinely available to the patient suspected of harbouring a brain tumour.

Acknowledgments

The authors wish to express their thanks to Professor W. V. MAYNEORD and Professor D. W. SMITHERS, in whose Departments this work was carried out, for their continuous support. They are particularly grateful to Mr. WYLIE MCKISSOCK, many of whose patients were included, and who was responsible for making possible the facilities at the Atkinson Morley Hospital, kindly provided by the Board of Governors of St. George's Hospital. Valuable assistance has been given by numerous members of the staff of the Institute and Hospitals concerned. The Isotope Division of the United Kingdom Atomic Energy Authority, A. E. R. E., Harwell, were most helpful in arranging the numerous pile irradiations that are needed for extensive work with K^{42}.

The collimated scintillation counter was manufactured by Ekco Electronics, Ltd., and the needle Geiger counter by Twentieth Century Electronics, Ltd.

The work was supported by grants from the Medical Research Council.

SUMMARY

Various substances have been shown, by using radioactive tracer methods, to concentrate more in tumours than in normal tissue and various attempts have been made to use this effect in the detection and localisation of brain tumours. Some of the limitations of the method are discussed. An account is given of recent clinical investigations using K^{42}. Initially, measurements were made of the uptake of K^{42} in tumour specimens obtained at operation on patients to whom this isotope had previously been administered. Subsequently, external counting surveys were made of the intact skull. The results of such surveys on 80 patients are reported, and discussed. Whilst the results are not very encouraging, it is considered that it may be possible to eliminate some sources of error and so increase the diagnostic value of the technique.

ZUSAMMENFASSUNG

Mit Hilfe von radioaktiven Spurmethoden hat es sich gezeigt, dass verschiedene Substanzen sich mehr in Tumoren als in normalen Geweben konzentrieren; mehrere

Versuche sind angestellt worden, um diesen Effekt für die Entdeckung und Lokalisierung von Hirntumoren zu benutzen. Einige Begrenzungen der Methode werden besprochen. Ein Bericht über kürzlich ausgeführte klinische Untersuchungen mit K^{42} wird abgegeben. Anfänglich wurden Messungen der K^{42}-Aufnahme in Tumorpräparaten gemacht, die man bei der Operation von Patienten erhielt, denen man diesen Isotopen vorher zugeführt hatte. Später wurden externe Messungen am intakten Schädel ausgeführt. Die Ergebnisse derartiger Untersuchungen an 80 Patienten werden berichtet und diskutiert. Die bisherigen Ergebnisse sind nicht sehr ermutigend. Man ist jedoch der Ansicht, dass es möglich sein mag, einige Fehlerquellen zu eliminieren und damit den diagnostischen Wert der Technik zu erhöhen.

RÉSUMÉ

Les méthodes de traçage radioactif ont montré que des substances diverses se fixent à plus forte concentration dans les tumeurs que dans le tissu normal, et on a fait différentes tentatives pour utiliser cette propriété pour la détection et la localisation des tumeurs cérébrales. Certaines limites de cette méthode sont étudiées. Les auteurs présentent les résultats de récentes recherches cliniques faites avec le K^{42}. Initialement ils ont mesuré la fixation de K^{42} sur des tumeurs prélevées opératoirement sur des malades à qui cet isotope avait été préalablement administré. Par la suite ils ont fait des examens par comptage externe sur le crâne intact. Ils présentent et discutent les résultats de ces examens sur 80 malades. Bien que les résultats ne soient pas très encourageants, les auteurs pensent qu'il doit être possible d'éliminer certaines sources d'erreurs et d'augmenter ainsi la valeur diagnostique de cette technique.

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FROM MASSACHUSETTS GENERAL HOSPITAL (DIRECTOR: D. A. CLARK), BOSTON, MASSACHUSSETTS, U. S. A.

SCANNING OF POSITRON-EMITTING ISOTOPES IN DIAGNOSIS OF INTRACRANIAL AND OTHER LESIONS

by

G. L. Brownell and *W. H. Sweet*

Radioactive isotopes have proved to be of value in the diagnosis of focal disorders of the brain. The biological behavior which permits these techniques to be used is a fundamental and poorly-understood property of the normal brain to exclude or to admit slowly a wide variety of substances ranging from normal intracellular ions to large organic molecules. This property has been described as a "blood-brain barrier", although the existence of a physical barrier is by no means proven. Thus, the following ions, P^{32}, K^{42}, Mn^{52}, Cu^{64}, As^{74}, and Rb^{84}, have been shown (5) to enter the normal cerebrum of mice much more slowly than spleen, liver, kidney, pancreas, adrenal, muscle or transplanted subcutaneous glioma. Our studies in man with radioactive substances have shown that trace ions, such as Mn^{52}, Cu^{64}, and As^{74} concentrate in brain tumors to a substantially greater degree than in normal brain; ratios of 10 : 1 or more are common. Labeled compounds such as diiodofluorescein (6) and iodine labeled albumin (7) also have similar properties. In our laboratory the normal intracellular ions, phosphate and potassium, have been found to concentrate to a greater degree in human brain tumor relative to normal brain than any other substances.

Numerous practical techniques have evolved from these observations. SELVERSTONE and WHITE (10) have demonstrated the use of P^{32} in localizing tumors at operation, and SELVERSTONE, SWEET, and ROBINSON (9) refined the techniques by using a fine Geiger-Mueller probe counter of 2 mm diameter for the localization.

MOORE (6) reported first the use of external counting for the localization of brain tumors, and numerous others (2, 4, 8) have reported observations with gamma-ray emitting isotopes with varying results.

Fundamentally, the problem of external localization of isotopes is twofold; obtaining a suitable resolution of measurement of activity within the head while maintaining the intensity, and presenting the information in a usable manner. The use of positron-emitting isotopes appeared to offer considerable promise for obtaining high resolution while maintaining the sensitivity at an appropriate level. Automatic scanning of the head and recording of data appeared useful in the presentation of results. The development of such a device, called the positron scanner, and preliminary results, have been described in previous reports (11).

We discuss here the result of positron scans on 719 patients, most of whom have received radioactive arsenic, As^{74}. These have been so encouraging for the detection of brain tumors that the method has been tried in numerous other situations where one wishes to know the distribution of an isotope deep within the body. Preliminary results of scanning of other organs in animals will be discussed.

Theory of scanning. A relationship between optimal concentration of isotope, resolution, and efficiency of detection may be derived. Thus, the required concentration in disintegrations per min. per cc (dpm/cc) is:

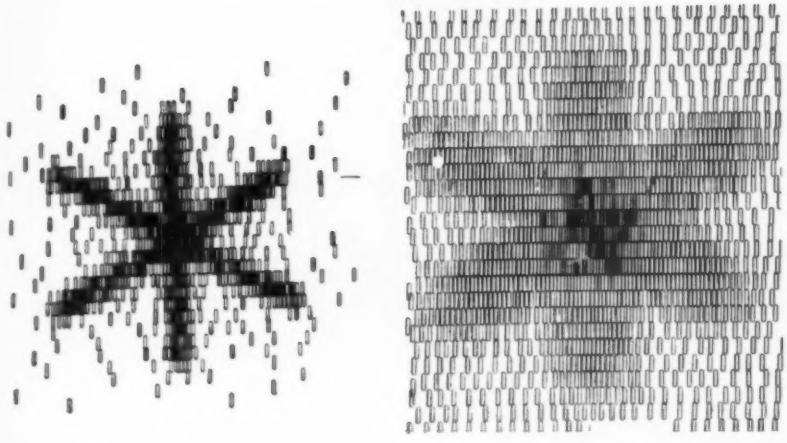
$$C = \frac{400\ A}{\pi^2 d^4\ L \varepsilon T}$$

where A = area to be scanned in cm^2
d = resolution of apparatus in cm
L = width of object to be scanned in cm
ε = efficiency (cpm of detector per dpm of isotope located at center)
T = time available for scan in min.

The required concentration of isotope is seen to be strongly dependent on the resolution of the device, regardless of the physical method of detection. As the maximum concentration is limited by biological considerations and is very roughly the same for most useful isotopes, the optimal resolution is primarily dependent on the efficiency.

Positron detection. The physics involved in the detection of positron radiation has been discussed in a previous report (3). Briefly, the positron undergoes a process of annihilation, producing two 0.51 MeV quanta called annihilation radiation which leave at 180° or "back to back". These two quanta are detected by two scintillation counters located on either side of the head and connected to a coincidence circuit.

The advantage of the coincidence method is that it allows increased resolution without loss of intensity. Fig. 1 shows scans on a geometrical pattern of activity in the form of a six-pronged star. The actual inner diameter of the tubes containing activity is only 2 mm and is small compared to the resolution. In (a) a pattern of As^{74} is scanned using coincidence detection with 2 cm apertures, while in (b) a pattern of I^{131} is scanned with a single detector with a collimator 15.84 cm in length and 1.65 cm diameter. The pulses from the single detector are analyzed and only the 360 keV photopeak is retained for plotting the scan. The increased resolution of the coincidence scan is obvious, whereas



a b

Fig. 1. Scans of star-shaped phantom consisting of 6 tubes of 2 mm I D containing a radioactive solution.

a) As^{74} scanned by means of coincidence detection with two detectors of aperture about 2 cm. b) I^{131} scanned by means of a single-channel collimator of 1.65 cm diameter and 15.84 cm length. Pulse height discrimination used to select the 360 keV photopeak. Length of symbol in both cases is 1 cm.

the efficiency of the coincidence system is still greater than that of the single channel system.

Resolution, as used in this report, is given the following arbitrary definition. If a point source of activity is moved transverse to the axis of the detector at a plane corresponding to the middle of the object being scanned, a characteristic curve is obtained having a maximum at the center and decreasing rapidly on either side. The distance between the two points at which the response has decreased to one-half its maximum value is called the resolution. Diagr. 1 shows the effect of aperture diameter on resolution for both a coincidence detecting system and a single channel system with a collimator 15.84 cm long. When all factors are considered, it appears that for equal resolution, the efficiency of the coincidence system is about 10 times that of the single channel system. Stated in other words, to produce a scan of a given resolution in a given time, the single channel techniques will require about 10 times the dose of isotope required by the coincidence technique using positron-emitting isotopes.

Brain Tumor Localization

The new version of the positron scanner will be described in detail elsewhere (1). Most of the scans to be reported here have been obtained with the original model which has been previously discussed (11). Both devices produce two scans, a positrocephalogram, or PCG, which shows the distribution of activity throughout the head, and an asymmetrogammagram, or AGG, which shows any asymmetry in activity from right

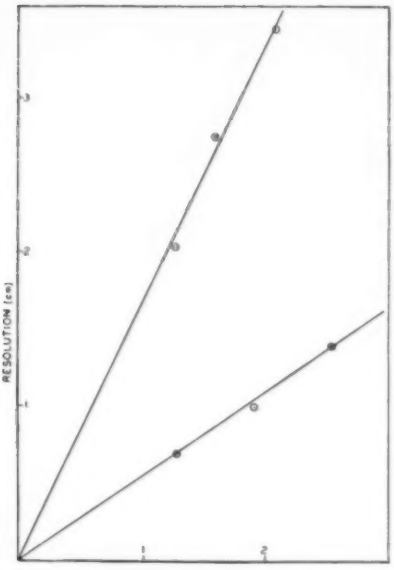


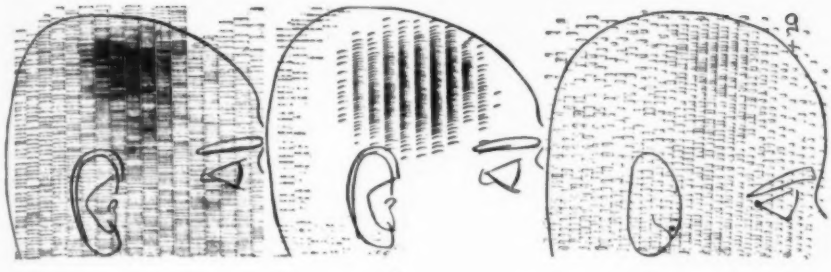
Diagram 1. Dependence of resolution on aperture diameter. The upper curve refers to a single-channel collimated detector of length 15.84 cm. The lower curve refers to coincidence detection of positrons. For a given resolution, the aperture diameter for the coincidence system is about 3 times that of the single channel system.

to left within the head. These two scans, obtained simultaneously, provide information on the exact location and extent of an abnormal region. All patients in the present group have received As^{74} and, in general, scans are obtained one hour following the intravenous injection and again on the following day. Both the arsenate and arsenite ions have been used, and our usual dose is 20 μc/kg body weight.

The normal PCG shows an increase in isotope content in the region of the face and around the periphery of the head. The area over normal brain shows a uniform and low content of activity. The normal AGG should in principle show no symbols, but usually shows a slight right or left unbalance over a portion of the scan. A tumor or abscess produces an abnormal area of isotopic concentration and may produce an indication on the AGG scan if the area is situated to one side at the midsagittal plane. Fig. 2 (a and b) show scans on a patient with a right-sided meningioma. The lateral extent is indicated by the marked area of concentration on the PCG, and the fact that the tumor is on the right is indicated by the cluster of curved symbols on the AGG. A left-sided tumor would be indicated by a cluster of straight symbols on the AGG. Note that the area covered by the curved symbols in the AGG (Fig. 2 b) is much larger than the actual area of the tumor which is shown faithfully by the PCG, Fig. 2 a. One day later on our new machine the PCG of Fig. 2 c was obtained. The dumbbell-shape of the tumor revealed at operation is visible only on this new scan at higher resolution.

Results

Table I summarizes the diagnostic accuracy of the method in patients with tumors; Table II covers the other categories of disease. For this study we have reviewed our scans on all 719 patients without reference



a b c

Fig. 2. Typical scans on a patient with a right-sided meningioma.
a) PGG at 1 hour shows the lateral extent of the tumor. b) AGG at 1 hour, taken simultaneously with the PGG (a), shows a cluster of curved symbols (right unbalance) over the area of the tumor. c) PCG of following day, taken on new machine shows effect of higher resolution. The dumbbell-shape of the tumor is more apparent from this scan.

Table I

Tumors

Category	Isotopic Concentration			
	Abnormal		Normal	
	I	II	III	IV
Gliomas				
Astrocytoma	7	7	2	7
Ependymoma	0	2	0	1
Glioblastoma	44	15	6	0
Medulloblastoma	0	0	2	2
Oligodendroglioma	1	0	1	1
Brain stem (usually unverified)	1	2	3	3
Meningioma	32	1	0	1
Acoustic neuroma	0	0	1	3
Hemangioblastoma, cerebellar	0	0	1	2
Craniopharyngioma	1	3	0	3
Pituitary adenoma	1	3	3	0
Epidermoid	0	0	1	0
Third ventricle (usually unverified)	1	1	0	3
Melanoma	2	0	0	0
Metastatic malignant	10	5	8	8
Lipoma of corpus callosum	0	0	0	1
Unclassified	2	1	3	0
Total	102	40	31	35
	(49 %)	(19 %)	(15 %)	(17 %)
	142		66	

Grand total 207. Abnormal concentration 69 %.

to our previous diagnostic descriptions or any clinical data. In certain cases several sets of scans have been obtained for one patient. We have classified our diagnoses into four groups:

I = abnormal isotopic concentration
II = probably abnormal isotopic concentration
III = probably normal isotopic concentration
IV = normal isotopic concentration

If the size and locus of the abnormality appear unequivocal and especially if there is agreement in all four scans, PCG and AGG on two successive days, we place the case in group one. If this data is consonant with a clinical history and findings indicating a space-taking lesion, we are omitting the slightly hazardous surgical diagnostic measures of pneumography and arteriography. When we consider that there is a probability but not a certainty of abnormality in the scans (group two), full diagnostic measures, including appropriate surgical studies, have usually proven advisable. Diagnosis of the probable normals (group three) and normals (group four) is derived from other data, but especially in group three repetition of the scan may prove fruitful. Although we have classified the group three scans as misses when a tumor was present, the suspicious area in the scan has often corresponded to the position of the tumor. The position of the abnormal uptake shown in the preoperative PCG has proven to correspond to the location of the intrinsic lesion — tumor or abscess — rather than to surrounding or distant edema. Hence the 1 : 1 reproduction given by the scan permits the surgeon to place his cerebral incision as well as his bone flap properly.

Table II

Non-Neoplastic Disease

Category	Isotopic Concentration			
	Abnormal		Normal	
	I	II	III	IV
Vascular				
Aneurysm	0	1	1	4
Arteriovenous malformation	1	1	1	2
Cerebral vascular accident	2	7	14	10
Intracerebral clot (verified)	1	0	0	2
Subdural hematoma	2	1	1	0
Abscess	3	4	1	1
Convulsive seizure, not due to above causes	4	7	25	27
Paget's disease	4	0	0	0
Orbital tumors	1	0	0	3
Other non-neoplastic disorders	2	13	43	99
Total	20	34	86	148

Tumors. Our greatest accuracy by far has been in the meningiomas which have a high uptake of the As^{74} even among the slowest growing, least vascular examples. We could, moreover, be certain of the abnormality in 32 of our 33 positive diagnoses. Two of these tumors were diagnosed and localized at a time when both arteriography and pneumography had yielded technically good, normal films and the abnormal PCG and AGG were crucially important in leading to early effective surgery. The only one we are aware of having missed was a tiny 6 gram tumor arising from the tuberculum sellae.

Our next highest percentage of accuracy is in the group of glioblastomas. In at least two of our six misses in these patients there was within the tumor a sizeable quantity of cystic fluid which often takes up even less isotope than does normal brain. The use of our new equipment with greater resolution may improve our accuracy both in these patients and in the substantial number, 16 of the metastatic lesions (52 %), in whom the total mass of tumor was too small for detection. However, even a small nodule may be detected if near the surface of the brain, and we have one example in our series of a decisively positive scan despite a normal arteriogram and pneumogram. Many of the metastases lie in the posterior fossa, a problem site for this method because of the thick muscular covering with a moderate As^{74} content. For example, we detected most of the supratentorial metastatic carcinomas and only one of the 5 in the posterior fossa. The corresponding figures for astrocytomas are 13 of 20 supratentorial (65 %) and only one of the 3 infratentorial lesions of this type. We also missed the 4 medulloblastomas and the 3 hemangioblastomas in the posterior fossa.

When the tumor is so situated that a small number of cells yields symptoms, such as occurs in the brain stem, third ventricle, and sellar region, our accuracy also drops sharply. Happily, here and in the posterior fossa other methods such as visual fields and/or pneumography are at their best so that this method is complementary to those now in general use. In the slow growing gliomas, the acoustic neuromas and the "congenital rest" tumors we do poorly, no matter where they are situated, because of the low differential uptake of the isotope. The major problem here is to secure some compound or ion of some isotope which will avidly enter these lesions.

In general our best results are obtained in tumors of the cerebral hemispheres, especially those near the surface. It is in just this type, which is likely to cause a few convulsions at an early stage, that prompt diagnosis has been out of reach. We anticipate that our method may make its greatest contribution in this field both for the initial diagnosis and the apprehension of recurrences. Serial scans, as often as indicated, are harmless to the patient, a feature which is also valuable in the

critically ill who may tolerate poorly intra-ventricular or intra-arterial injections.

Postoperatively, it is not fruitful to scan again for at least one month. Presumably, post-traumatic breakdown of the blood-normal brain barrier permits entry of isotope at the operative site even when tumor has been removed. Late scans may show asymmetry with higher uptake on the normal side just opposite the earlier site of tumor. We attribute this to the greater bulk of tissue on the normal side with a higher uptake than cerebrospinal fluid. These factors all make it necessary to have for comparison a late postoperative scan in order to diagnose early a recurrence of tumor.

Abscess. An unexpected dividend of the method has been the accurate localization in 7 of 8 scans of supratentorial abscesses. Even in a well encapsulated lesion, we have found that the pus as well as the capsule may contain large amounts of As^{74}. We missed one small parietal abscess and one within the petrous portion of the temporal bone.

Vascular lesions. Under the heading of cerebral vascular accident we have grouped the thrombotic and the few hemorrhagic lesions we have scanned. It will be noted that in 9 of the 38 patients in this group the scan was positive, but unequivocally so in only 2. In each of these the ictus was recent and later scans returned toward normal. The method is consequently proving a real help in spotting the patient with a tumor who improves markedly after an initially severe bout of symptoms. In this patient the original scan is more strikingly abnormal, and it improves but little on repetition. Of the other vascular disorders we note here only that we had 3 positive scans in unilateral hematomas and the only negative scan occurred when these lesions were bilateral and symmetrical.

Convulsive Seizures. If our study is carried out within 48 hours of a convulsion, especially a focal one, a positive scan may ensue. The 11 positives out of 63 patients (with seizures not caused by one of the foregoing diseases) were found mainly in the early post-ictal phase. Hence, it is advisable to defer the study for two days after a seizure, if feasible, in order to avoid the temporary clouding of the diagnostic inferences by the transitory breakdown of blood-brain barrier in the region of epileptically discharging cortex.

Paget's Disease. There is a marked uptake of As^{74} in the diseased skull in this disorder. All 4 scans showed diffuse dense marking, especially in the frontal regions.

Orbital Tumors. In the 4 lesions studied, all of which produced exophthalmos, only 1, a subfrontal mucocele, yielded a positive scan.

Other Non-Neoplastic Disorders. This comprises a heterogeneous group of nearly all other diagnostic categories in which an intracranial mass

lesion might be suspected. A number of these patients had no organic disease of the central nervous system, had *e. g.*, Ménière's syndrome, labyrinthitis, psychoneuroses, or psychosis. They comprise as normal a group as we have. As the table shows, in only about 10 % of these is the scan suggestive of a focal lesion and in only 2 patients was there an unequivocal abnormality of the distribution of isotope. In one of these, the abnormal scans corresponded with bizarre clinical findings, but the patient improved and the nature of the disease was not determined.

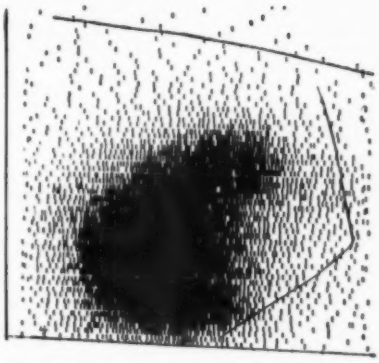


Fig. 3. Scan of liver of dog following intravenous injection of Cu^{64}. The scan is a lateral view of the dog.

Preliminary Results for Other Organs

Studies have been carried out on scanning other organs of the body such as liver, pancreas, kidney, and lung with various positron-emitting isotopes, including Cu^{64} and Zn^{62}. The preliminary results offer promise that successful tests will be developed for diagnosing disorders of these organs.

Fig. 3 shows a typical scan of the liver of a dog obtained one half hour after an intravenous injection of Cu^{64}. The liver concentrates nearly 80 % of the dose of Cu^{64} and quite detailed scans may be obtained.

SUMMARY

The authors have automatically scanned the head, after intravenous injection of As^{74}, to obtain simultaneously two types of data. The *positrocephalogram* (PCG) localizes any abnormal uptake in the sagittal plane. The other, the *asymmetrogammagram* (AGG), indicates the degree of removal from the midline toward one side or the other of such abnormality. Data evolve pictorially; preparation and interpretation require but a few minutes. Nearly all meningiomas and the great majority of tumors and abscesses of the cerebral hemisphere are delineated so precisely that the surgeon may often proceed without arteriogram or pneumogram. With the exception of fortuitous arteriographic demonstration of neoplastic vessels no other method directly portrays the lesion itself. For other neoplastic types and loci, our method is much less accurate. It does, however, aid in differentiating tumor, abscess or subdural hematoma from cerebral vascular thrombosis or hemorrhage.

ZUSAMMENFASSUNG

Die Verfasser haben nach intravenöser Injektion von As^{74} den Kopf automatisch untersucht um gleichzeitig 2 Typen von Ergebnissen zu erhalten. Der eine, Positrocephalogramm (PCG) bezeichnet, lokalisiert jede abnorme Aufnahme in der Sagittalebene; der andere, Asymmetrogammagramm (AGG) genannt, gibt die Grösse des Abstandes von der Mittellinie zu einer derartigen Abnormität. Die Ergebnisse werden tabellarisch vorgelegt; Ausarbeitung und Deutung erfordert nur wenige Minuten. Nahezu

alle Meningeome und die grosse Mehrzahl von Tumoren und Abszessen der Hirnhemisphäre werden so genau beschrieben, dass der Chirurg oftmals ohne Arteriogramm oder Pneumogramm weiter arbeiten kann. Mit Ausnahme der gelegentlichen arteriographischen Darstellung neoplastischer Gefässe bietet keine andere Methode eine direkte Abbildung des krankhaften Prozesses selber. Die Methode ist für andere neoplastischen Veränderungen und Lokalisationen weniger genau; sie erleichtert jedoch die Differentialdiagnose zwischen Tumor, Abszess oder Subduralhämatom einerseits und Gefässthrombosen oder Blutungen andererseits.

RÉSUMÉ

Les auteurs ont exploré automatiquement la tête, après injection intraveineuse de As^{74}, pour obtenir simultanément deux types de renseignements: l'un appelé positrocéphalogramme (PCG) qui localise toute fixation anormale dans le plan sagittal, l'autre appelé asymétrogammagramme (AGG) qui indique la distance d'un côté ou de l'autre de la ligne médiane à laquelle se trouve cette anomalie. Ces données s'enregistrent sous forme de schéma; la préparation et l'interprétation ne demandent que quelques minutes. Presque tous les méningiomes et la grande majorité des tumeurs et des abcès des hémisphères cérébraux sont dessinés avec une telle précision que le chirurgien peut souvent intervenir sans artériographie ni pneumographie. A l'exception de la mise en évidence occasionnelle, par artériographie, de vaisseaux néoplastiques, aucune autre méthode ne dessine directement la lésion elle-même. Cette méthode est moins précise pour les autres types de néoplasies et pour les autres localisations, mais elle aide à distinguer les tumeurs, les abcès ou les hématomes sous-duraux des thromboses vasculaires et des hémorrhagies cérébrales.

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FROM THE SPINAL INJURIES CENTRE (DIRECTOR: DR. A. G. HARDY), LODGE MOOR HOSPITAL, SHEFFIELD, ENGLAND

BONE, JOINT AND SOFT TISSUE CHANGES FOLLOWING PARAPLEGIA

by

Thomas Lodge

The fact that changes take place in the skeletal bony and soft tissues in paraplegic patients has been known for many years but when the causative lesion in the spine was of neoplastic or inflammatory origin and the prognosis depended largely on the primary lesion, few patients survived long enough for observations to be made on secondary lesions of a non-lethal character in the trunk and limbs below the level of the cord lesion.

The main factors in increasing the number of cases of paraplegia were war injuries and industrial accidents especially those occurring in coal-mines when fractures or fracture-dislocations of the vertebrae may be accompanied by severe damage to or transection of the spinal cord or cauda equina. In both war and industrial injuries the subjects are most often young men otherwise fit who, if they survive the initial injury may be expected to live for varying periods up to many years although paralysed from the waist downwards. Longer survival has made possible the discovery and investigation of changes occurring in the lower limbs and the larger numbers of traumatic paraplegics have facilitated estimations of the incidence of these complications.

The first major descriptions of the soft-tissue changes were those of Madame DÉJERINE and her co-workers in 1918 and 1919 and they still constitute the greatest contribution to the subject.

The other great contributory factor to the discovery of bone and soft tissue lesions in paraplegics has been the increasing use of radiography, since, owing to the absence of sensation below the level of the cord lesion, the patient himself may be quite unaware of their existence. The earliest discoveries were those of new bone formation around the hip joints seen

on 'scout' radiographs of the pelvis usually taken to confirm or exclude the presence of vesical calculi.

For the purpose of this paper I have reviewed the radiographs of 236 paraplegic patients treated at the Spinal Injuries Centre of the Sheffield Regional Hospital Board. These patients were seen during the 10 year period 1945—1955. In 84 % the spinal lesion was due to injury, the great majority being attributable to industrial accidents. In this series the distribution of the spinal lesions in the 178 cases in which it could be determined was as follows: cervical spine — 17; upper dorsal — 11; lower dorsal (down to the 10th vertebra) — 19; dorso-lumbar (that is from 11th dorsal to 1st lumbar vertebrae) — 114; lumbar — 17.

I. *Changes in bone.* Many series of cases have now been published by different authors but all have found that such changes as occur in bone as well as those that take place in joints and soft tissues are confined to the parts of the body below the level of the neurologic lesion. This is confirmed in the present author's series.

The commonest occurrence is osteoporosis or decreased bony density which is almost invariably seen in the leg bones and usually also in the pelvis since the majority of spinal injuries involve the dorsal or lumbar regions.

Osteoporosis is not easily diagnosed unless it is well marked. In the present series minor degrees of osteoporosis could not be established particularly on the frequently poor quality films obtained on paraplegic patients. In assessing osteoporosis I have used the following criteria.

a) In the pelvis:

1. Extreme loss of density (minor degrees of apparent porosis may be artefacts due to radiographic factors).
2. Accentuation of the normal differences between the medulla and cortex.
3. Localised zones of decreased bony density as for example around the acetabulum.
4. Speckled areas of rarefaction.
5. Marked decrease in the number of trabeculations, the remaining ones being more widely-spaced.

Judged by these criteria, osteoporosis of varying degrees was seen in 127 out of the 181 pelves which were radiographed; in 27 patients the pelvic bones were normal and in the remainder no opinion could be expressed.

b) In the long bones:

1. Relative thinning of the cortex. This was mostly seen towards the ends of the bones, especially the lower ends of the femora.
2. Localised or diffuse diminution of bone density and decrease in the number of trabeculations.

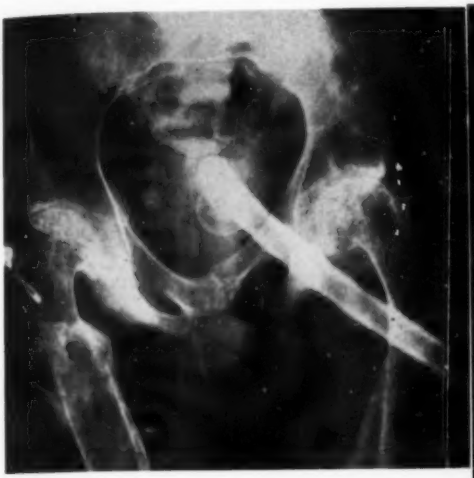

Fig. 1

Fig. 1. Osteoporosis of the pelvis and femora in paraplegia. Thinning of cortex, loss of bone density, ankylosis of pubis.

Fig. 2

Fig. 2. Osteoporosis around the knees with thinning of cortex, loss of bone density and widely spaced trabeculations.

Almost always where there was porosis of the leg bones, it was most marked around the knee joint, being frequently epiphyseal in distribution. In a number of cases it was most obvious along the lines of attachment of the joint capsule to the femur and tibia. Rarefaction of the leg bones was seen in 94 out of 103 patients whose legs were radiographed, the remaining 9 having normal bone density. Almost all the patients with lesions at the dorso-lumbar junction showed osteoporosis of the spine and legs and in 6 cases with no such porosis the lesion was either in the cervical, upper dorsal or lumbar region.

Fig. 3

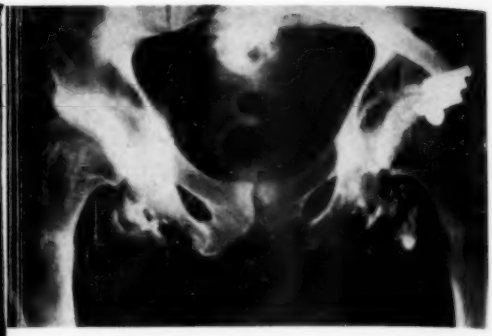

Fig. 4

Fig. 3. Boy aged 11. Pathologic supracondylar fracture following minimal trauma. Extremely thin cortex and large calcifying subperiosteal haematoma.

Fig. 4. Erosion of both ischia in paraplegia with new bone attached to ischia and extending into the tissues. This new bone contains clear spaces or lacunae.

A rare complication of the osteoporosis is fracture. These fractures are really pathologic fractures and may be due to injury or to ordinary handling as in physiotherapy. In two patients with extreme osteoporosis, supracondylar fractures of the femur were seen (one patient having bilateral fractures) and in all these 3 fractures there was a great excess of subperiosteal new bone, the ossification presumably taking place in a haematoma. Figs. 1, 2 and 3 show the extreme thinning of the cortex which predisposes to fracture in these cases. Both the osteoporosis and the subperiosteal haematoma suggest a possible deficiency of Vitamin C as well as a high degree of vascularity.

Erosion of bone takes place over the pressure points. The sacrum showed circular areas of erosion in 6 cases, the greater trochanter was flattened, atrophied and eroded in 11, and there were changes in the ischial tuberosity on one or both sides in 39 patients, as follows: in 6 there was erosion only, in 9 there was new bone formation on the ischium without erosion and in 24 there was both erosion and new bone formation.

With better treatment of the skin and the constant turning of patients in recent years the effect of pressure is relieved and changes over the pressure points are less common.

When new bone is formed over the ischia it has a 'whiskered' appearance as if pulled out from the bone itself. It then extends for a short distance

Fig. 5. New bone formation near but not attached to the left ischium in traumatic paraplegia.

Fig. 6. Traumatic paraplegic male aged 22. Erosion of greater trochanter by pressure. Reactive sclerosis of the bone and early new bone formation above and below the trochanter.

into the tissues and after a time ceases to grow any further. It is then seen as well formed bone of good density with a definite trabecular structure containing lacunae in which no bone has formed.

As in other situations this bone evolves to a certain stage and then remains unaltered indefinitely, although in one of the author's cases it seemed to undergo absorption. In a minority of cases, this new bone is associated with nearby decubitus ulcers.

In most patients the new bone is attached at some point to the ischium (Fig. 4) but there is at least one example of its complete detachment (Fig. 5). The great trochanter may be rarefied and flattened as if rubbed away by pressure (Fig. 6). Sometimes a reactive change is seen and the bony sclerosis appears to extend upwards and downwards from the trochanter in the form of new bone in the tissues. In addition, true new bone may form above the trochanter (Fig. 7). It is often quite separate from the trochanter and usually up to $^1/_2$" in diameter but it may be massive. Often the trochanter remains normal although there is ossification in the tissues above it (Fig. 8). Such ossification was seen in 16 of the present cases.

II. *Changes in joints.* It is worthy of note that in spite of often gross ossification *around* a joint there is usually little or no change *within* the

Fig. 7. Erosion of greater trochanter with rarefaction. New bone forming above the trochanter.

Fig. 8. Relatively normal great trochanter with new bone formed in tissues above it.

joint. It might have been expected that radiologic changes of the kind seen in Charcot's joints would be common in paraplegics but in fact they are not. DÉJERINE thinks that fundamentally the conditions in the joints are the same as in tabetic Charcot's joint but the paraplegic joint does not go on to articular erosion and disorganisation because it is not subjected to the same weight bearing stresses. In four patients there was loss of joint space and destruction of the articular surfaces in one hip joint, and two of them went on to disruption of the joint and dislocation.

I have observed in the sacro-iliac joints in 7 of the 181 patients whose pelves were radiographed, changes consisting of narrowing of the joint spaces with small articular erosions not unlike the appearances seen in ankylosing spondylitis. Indeed in two cases the joints were ankylosed. Recent work by ROMANUS and YDÉN on ankylosing spondylitis suggests that infection in the prostate may be an aetiologic factor in this disease. If this should prove to be true, it may also have a bearing on the sacro-iliac changes in paraplegics who frequently have some infection of the lower urinary tract.

Osteitis pubis was seen in only 2 cases, a feature which may also be due to urinary infection but in 4 patients a small symmetrical erosion was noticed on the anterior surface of the pubis.

III. *Changes in soft tissues.* The most prominent finding in this as in most other series of paraplegics is that of ossification and calcification

Fig. 9. Paraplegic aged 21. Massive new bone formed around the hip joint, chiefly anteriorly but the joint space is preserved.

Fig. 10. Lateral view showing massive new bone anterior to hip joints in paraplegic patient. Absence of change in hip joint itself.

in the muscular tissues below the level of the spinal lesion. There are certain well-established features originally described by DÉJERINE and confirmed by later writers and also in the present series: the changes are only seen below the level of the lesion in the cord (in fact they are never above the pelvis or below the knee); the masses of ossification may be single or multiple; they usually appear early, progress rapidly until they have reached a certain size which varies considerably from case to case, and then remain unchanged. The joints themselves are not involved and are often capable of considerable passive mobility. Their frequency has been variously estimated. DÉJERINE found an incidence of 48.7 %, LIBERSON 53.3 %, ABRAMSON 44 %, SOULE 37 %, but MILLER and O'NEILL found only about 4 %, possibly because their patients were not radiographed as a routine. In our cases the incidence was about 33 % but as we did not take radiographs of the legs in all the patients, the true frequency in our series may in fact be higher than this figure.

a. Ossification around the hips. I have seen new bone formed around the hips in 18 cases but there is no reliable record of when it first appeared. ABRAMSON says such ossification may start as early

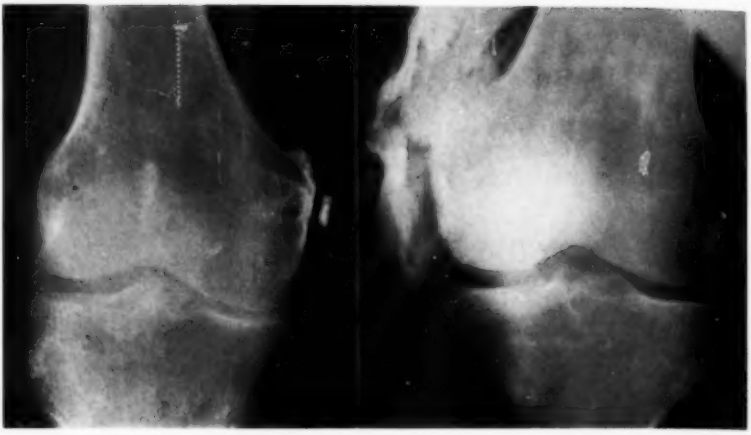

Fig. 11. Young paraplegic. New bone formation near medial condyle of femur.

Fig. 12. Unusual type of massive new bone formation around medial femoral condyle.

as 20 days after the injury but most authors consider 40 days a more probable lower limit. In some of our cases, the new bone was not present within six months of the injury but developed later. BRAILSFORD considering neuropathic joints in general believes that the calcium is taken from the nearby bone, deposited in connective tissue rather than muscle, and, during the second month after its deposition, is organised into bone, producing a 'frayed cotton-wool' appearance on the radiograph.

Around the hip, the new bone is seen in 3 places: *anteriorly* from the region of the anterior inferior iliac spine down to the inter-trochanteric line in which situation it may be massive; *posteriorly* where a band extends from the ischium to the posterior edge of the great trochanter; and *inferiorly* where a bridge of bone, usually slender, passes from the inferior pubic ramus to the lesser trochanter. Examples of these ossifications are shown in Figs. 9 and 10. Biopsy has shown this bone to be mostly spongy but it is said to be compact where it is attached to the ilium. Ossification around the hip is sometimes called the peri-articular type.

b. Ossification around the knees. This type, which DÉJERINE christened peri-epiphyseal, starts close to the condyle of the femur, usually the medial condyle but occasionally the lateral, and bears a close resemblance to the ectopic bone known as the Pellegrini-Stieda lesion (see Fig. 11). It develops as a flake alongside the condyle and is usually small and projects proximally, though a few cases have been described in which it grows distally beyond the level of the tibial plateau

(Fig. 12). The ossifications around the knee are not usually large but rarely massive deposits occur. There were in our series 15 examples of ossification around the knee.

c. Ossification in the thighs. These ossifications (the peridiaphyseal type) are the most striking of the radiologic manifestations of paraplegia and perhaps the most interesting. I have seen 14 such cases. DÉJERINE indicates that they start as bony needles in the inter-fascicular connective tissue rather than in muscle tissue proper and she states that they have no connection with bone except where they impinge upon it and even there the connection is by contiguity rather than continuity (see Fig. 13). Whilst this is no doubt true for the majority of examples, there is undoubtedly a type of peri-diaphyseal bone which is sub-periosteal, and the present series includes a few examples in which the new bone can be seen extending up the femoral diaphysis quite apart from those gross cases of sub-periosteal ossification following pathologic fractures (Fig. 14). The masses occurring underneath and between the muscle bundles have the appearance of trabeculated bone which histologically has been shown (*e. g.* by DÉJERINE, MILLER and O'NEILL) to contain trabeculations, Haversian systems, fatty marrow, osteoblasts and an investing periosteum.

Fig. 13. Examples of new bone formation in soft tissues of thigh, not apparently connected with periosteum.

There have been many theories to account for this ossification in the soft tissues but none are entirely satisfying. There is little or no evidence that haemorrhage or infection predisposes thereto and blood chemistry studies have not revealed anything of significance. GILIBERTI carried out experiments on dogs and rats but failed to find any significant difference in the mineral content of paralysed bones as compared with normal bones.

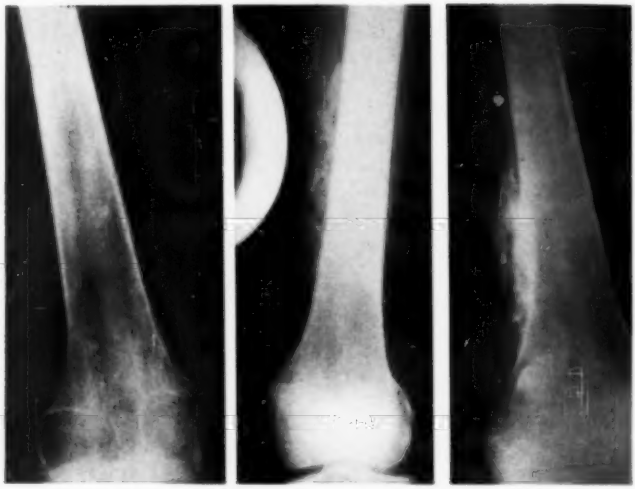

Fig. 14. Examples of new bone formation in the thighs of three different paraplegics. In these cases the new bone does appear to be close to the periosteum.

It is well-known that recumbency promotes the mobilisation of calcium from the bones and possibly this is an aetiologic factor. DÉJERINE believes that the oedema which occurs in paralysed limbs promotes the development of new bone in the tissues and that the phenomenon is really a metaplasia arising from the fact that primitive connective tissue can differentiate in the direction of bone formation under certain conditions. She and her colleagues suggest that these conditions may be supplied by the state of oedema together with trophic influences following irritation of the lateral sympathetic column in the spinal cord.

Acknowledgment

I would like to thank Dr. A. G. HARDY, Consultant in Charge, Sheffield Spinal Injuries Unit for making available the case notes of his patients and radiographs taken at other hospitals.

SUMMARY

A brief review is given of radiologic changes in the pelvis and lower limbs of paraplegic patients.

ZUSAMMENFASSUNG

Der Verfasser gibt einen kurzen Überblick über die radiologischen Veränderungen im Becken und den unteren Extremitäten paraplegischer Patienten.

RÉSUMÉ

L'auteur décrit brièvement les modifications radiologiques du bassin et des membres inférieurs chez les paraplégiques.

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FROM THE DEPARTMENT OF RADIOLOGY, UNITED OXFORD HOSPITALS, AND THE NUFFIELD INSTITUTE OF MEDICAL RESEARCH, UNIVERSITY OF OXFORD, ENGLAND

RADIOLOGIC INVESTIGATION OF PHARYNGEAL AND LARYNGEAL PALSY

by

G. M. Ardran and *F. H. Kemp*

In clinical practice the investigation of disabilities of swallowing is mainly confined to patients who are suspected of having developed a carcinoma. Patients with neurologic disorders are seldom referred for radiographic examination, on the grounds that the information obtained is of little value. Our purpose is to urge that this policy should be changed.

The function and innervation of many of the intrinsic and extrinsic muscles of the pharynx and larynx is either not known or imperfectly understood. For this reason, anatomical and physiological research has been our main aim; our enquiries have been assisted by the examination of patients with known neurologic defects.

From the clinical standpoint we now have sufficient experience of neurologic disorders to draw the following conclusions. Firstly, a radiologic examination will usually help to provide clearer understanding of the nature and extent of the patient's disability. Secondly, abnormalities of behaviour causing no symptoms may be revealed, thereby widening the clinical concept of the nature and extent of the neurologic defect. Thirdly, lesions due to other causes are frequently found in patients with neurologic abnormalities, especially when swallowing difficulties develop in patients who have had recognised neurologic complaints for many years and when disabilities develop in the elderly. In some instances the information obtained by radiologic study has influenced treatment.

It is essential that the radiologist should be familiar with the history and clinical findings, and particularly note the following points: abnormality of breathing, voice, or swallowing, prior to the patient's complaint and any history of injury or treatment to the structures of the neck

e.g. crico-thyroid puncture from bronchography, tracheotomy, operations upon the thyroid gland or lymph nodes, radiotherapy etc. Particular attention should be paid to a history of tonsillectomy. Prior to the roentgen examination the patient should be examined to ascertain whether there has been any mutilation of the soft palate or fauces, since injury to these structures may result in abnormal naso-pharyngeal closure or defective pharyngeal clearance. The patient should also be examined to ascertain whether there is any clinical evidence of distortion or asymmetry of the larynx since these factors alter the appearances seen in the antero-posterior projections and may influence swallowing.

We have recently examined two patients with swallowing difficulties attributed to a previous attack of bulbar poliomyelitis. In the first case, roentgen examination demonstrated defective action of the middle pharyngeal constrictor; on further enquiry the patient disclosed a history of injury to the neck in an aeroplane accident resulting in swallowing difficulty and change in voice persistent up to the time of onset of the poliomyelitis. In the second case the roentgen examination showed many abnormal features; further enquiry obtained a history of an operation upon the thyroid gland and subsequent roentgen therapy for alleged carcinoma of the thyroid. The roentgen findings in both these cases were not typical of the changes resulting from poliomyelitis (ARDRAN, KEMP and WEGELIUS).

Radiologic methods

The nature of the investigation must be varied to suit the individual patient's requirements. The methods include conventional radiography, fluoroscopy, tomography, and cineradiography with or without the aid of contrast media. The following is a brief account of our practice.

Conventional radiography. Lateral roentgenograms of the neck are used to record the movements of the soft palate and closure of the naso-pharyngeal aperture; for this purpose 2 cc of barium suspension are injected into the nostrils, the patient being postured so as to allow the barium to outline the upper surface of the soft palate and the walls of the epipharynx. Films are taken during quiet respiration and while the patient articulates the vowel 'e'; if he is able to do this, he is asked either to make other suitable sounds or to use a 'carnival blower'. Lateral roentgenograms may also be used to demonstrate closure of the laryngeal vestibule in cases where weakness of the vestibular sphincters is suspected. Films should be taken during quiet breathing, on articulating 'ee', and on bearing down as in defaecation or parturition (ARDRAN, KEMP and MARLAND 1954).

Antero-posterior roentgenograms are sometimes of value in patients suspected of pharyngeal paralysis. Films are taken during quiet breathing and while the patient tries to breathe out against closed nose and lips; the weakened pharyngeal wall balloons. This technique has only a limited application as many patients have other neurologic lesions which make it impossible for them to co-operate. Antero-posterior projections are also of value in certain patients suspected of laryngeal paralysis. Various techniques for this purpose have been described (LINDGREN 1939, SCHOEN 1953, and ARDRAN and KEMP 1953); films are taken on quiet respiration, on saying 'ee', and on bearing down. In our experience these methods are not suitable for general application, being not so easy to perform as tomography. The technique we have described requires an exposure time of only 0.005 sec which sometimes makes it possible to obtain good films in cases where tomography has failed because of blurring due to movement during the relatively long

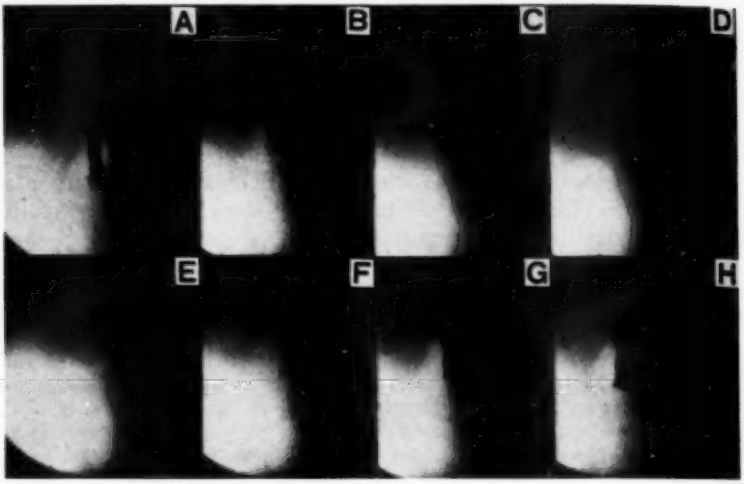

Fig. 1. Defective pharyngeal clearance following bulbar poliomyelitis. Normal laryngeal sphincteric mechanism. Woman aged 26. A. At rest. Contrast residue from previous swallow. Larynx open. B. Bolus descending through mesopharynx. Larynx still open. C. Further descent of bolus. Larynx closed. D. Bolus passing down oesophagus. E and F. Tongue arched backwards. No movement of posterior pharyngeal wall forwards to meet tongue. Defective clearance of the bolus from the pharynx. G. Airway being restored. Large residue. H. At rest. Large residue.

exposure time of 0.5 sec required. We have no experience of RETHI's technique (1912) using intrapharyngeal films.

Fluoroscopy (plus supplementary films). We use fluoroscopy as a preliminary investigation for most of our cases. It is, however, unsuitable for the investigation of severe cases of pharyngeal paralysis, very sick patients, and young children.

We believe that cineradiographic examinations should be made of all patients having swallowing abnormalities whose fluoroscopic examination appears normal.

Tomography. We use tomography for the investigation of suspected cases of laryngeal palsy (ARDRAN, KEMP and MARLAND 1954). For this purpose routine examinations comprise antero-posterior projections at 0.5 cm levels through the larynx during quiet breathing, on bearing down, and during a sustained vowel 'ee'. In interpreting the films care is taken to exclude local inflammatory processes that may simulate laryngeal palsy. We have no experience with units of the LINDBLOM or VALLEBONA types.

Cineradiography. Routine procedure comprises films taken at 25 frames per second with image intensification, the average duration of each film being 3 to 4 seconds. The average dose is 1 r per 100 frames. More than 12 films are seldom required. Films at 50 frames per second are sometimes taken. The applications of this method are now considered.

This paper is illustrated by cinefilms of four patients showing various causes of defective pharyngeal clearance (Figs. 1—4).

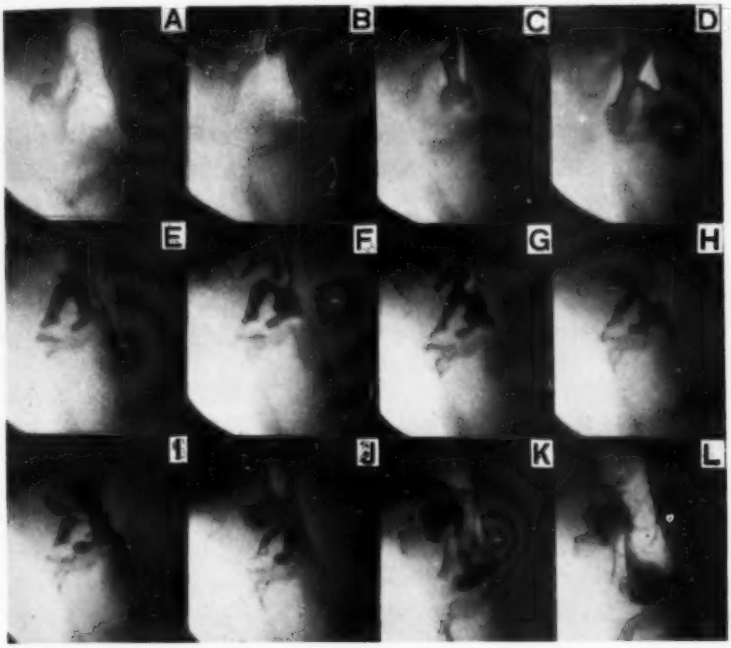

Fig. 2. Defective pharyngeal clearance in male aged 60 with muscular dystrophy. Laryngeal sphincter weakened. A. At rest. B. Descent of bolus. C. Further descent. Larynx still open. D. Filling of lateral food channel, pyriform fossae and laryngeal vestibule. E. Partial closure of laryngeal vestibule. Some contrast medium in laryngeal ventricle and through vocal cords. F and G. Residue after clearance of bolus. H. Descent of another bolus. Epiglottis tilted backwards against posterior pharyngeal wall. I. Bolus entering oesophagus. Some forward movement of posterior pharyngeal wall. Epiglottis not downturned. J. Re-aeration of pharynx beginning. Closure of crico-pharyngeus. K. Further re-aeration. L. Re-aeration complete. Large residue in vallecula and large food channels. Traces of contrast medium in larynx and trachea.

Palato-glossal closure. Films taken comprise lateral projections of swallowing in the erect and supine position, sucking barium through a straw in the erect position and while chewing.

Abnormalities of the mode of closure have been seen in patients suffering from scleroderma (ARDRAN, KEMP and TRUELOVE 1953) and in patients recovering from bulbar poliomyelitis. In all cases closure was effective.

Defective closure, with spill into the pharynx on chewing or on holding the bolus in the mouth while supine, has been seen in many patients after tonsillectomy in whom the anterior pillars of the fauces have been damaged.

The movements of the tongue. Antero-posterior and lateral projections are taken with the subject erect, swallowing a fluid barium bolus, and saying 'ee' and 'ah', the tongue being coated with barium from the previous bolus.

The abnormalities observed include the following:

1) Deflection of the bolus. In hypoglossal nerve palsy the bolus is swallowed by being deflected over the affected side of the tongue and not over the midline as in the normal individual. A similar type of deflection is seen in patients who have an operative defect of the side of the face, as, for example, after an operation for carcinoma of the maxillary antrum. Deflection of the bolus to one or both sides of the tongue is usually seen during swallowing in patients with a cleft palate (ARDRAN and KEMP 1955).
2) Limitation of movement due to fibrosis or infiltrative processes such as myositis or scleroderma has been seen. Such disorders may simulate neurologic lesions, such as myositis or motor neuron disease, in their early stages.
3) Weakness and/or slowness of movements may be seen in many conditions. In myasthenia gravis the action is improved by prostigmin.
4) Disordered or dysrhythmic movements have been noted in various states resulting in spasticity.
5) Defective clearance of the bolus from the mouth. The tongue may fail to clear the whole of the bolus from the mouth if there are any of the disorders (1)—(4).
6) Failure to initiate a swallowing reflex has been observed in some young babies; they have been able to regurgitate normally.

Naso-pharyngeal closure. After barium suspension has been injected to outline the soft palate and walls of the epipharynx, films are taken in the lateral projection of swallowing in the erect and supine positions, and on saying 'ee'. If 'ee' is articulated badly the patient should be asked to make other suitable sounds or to use a 'carnival blower'.

The normal closure is due to elevation of the soft palate by the levator palati muscles and stretching of the anterior segment of the soft palate. The nasopharyngeal sphincter tightens the pharyngeal wall around the elevated palate. The posterior pharyngeal wall is brought forwards, forming Passavant's cushion or ridge, which is well demonstrated by radiography. The size of the gap to be filled is also important if the palate is short or if there are adenoids.

The abnormalities observed include:

1) Defective elevation with poor formation of the levator palati eminence — seen in some patients with bulbar palsy and after surgical excision of the uvula.

2) Defective formation of Passavant's cushion or ridge seen in patients showing muscular weakness, including those with general debility and in some cases after bulbar poliomyelitis.
3) Spill into the epipharynx in the supine position when swallowing a large bolus has been seen when either (1) or (2) were noted.
4) Inability of the soft palate to fill the gap due either to small size or defective stretch has been encountered in certain patients with cleft palate and others in whom the palate was intact.
5) Abnormal pattern of palatal movements, closure being apparently effective, as seen after bulbar poliomyelitis.

Pharyngeal clearance. Lateral and antero-posterior projections of swallowing are taken in the erect and supine positions. In patients with clinical signs of pharyngeal dysphagia, especially young children, old people, and persons otherwise weakened or debilitated, it is necessary to proceed with caution. The number of films taken may have to be curtailed to a single lateral projection during swallowing. In cases of severe dysphagia 0.5 to 2 cc of barium suspension should be injected into the mouth with a syringe with an attached short flexible tube. The wet films of a lateral projection of the neck covering the laryngeal area should be inspected before proceeding with the examination. Unnecessary delay or protracted examinations should be avoided. In many such patients it is desirable to use ward mobile roentgen apparatus.

The abnormalities observed include:

1) Absence or weakness of movements, which may be due to various causes, such as poliomyelitis, polioneuritis, muscular dystrophy, general debility or infiltrative processes (scleroderma).
2) Inhibition of pharyngeal movements due to obstruction in the oesophagus.
3) Disordered movements may be seen with partial paralysis.
4) Deflection of the bolus — the bolus is deflected to the affected side in patients with predominantly unilateral paralysis.
5) Absence of swallowing movements (presence of reverse movements as in vomiting) encountered in some newborn children with swallowing difficulties.
6) Failure of the epiglottis to turn down normally. During swallowing in all cases of severe pharyngeal palsy the epiglottis is not turned down over the entrance to the larynx as in normal individuals. It is usually tilted downwards on the side down which the bolus passes. When the bolus has passed there may be a residue left immediately over the entrance to the larynx as in cases in which the tongue of the epiglottis has been removed.

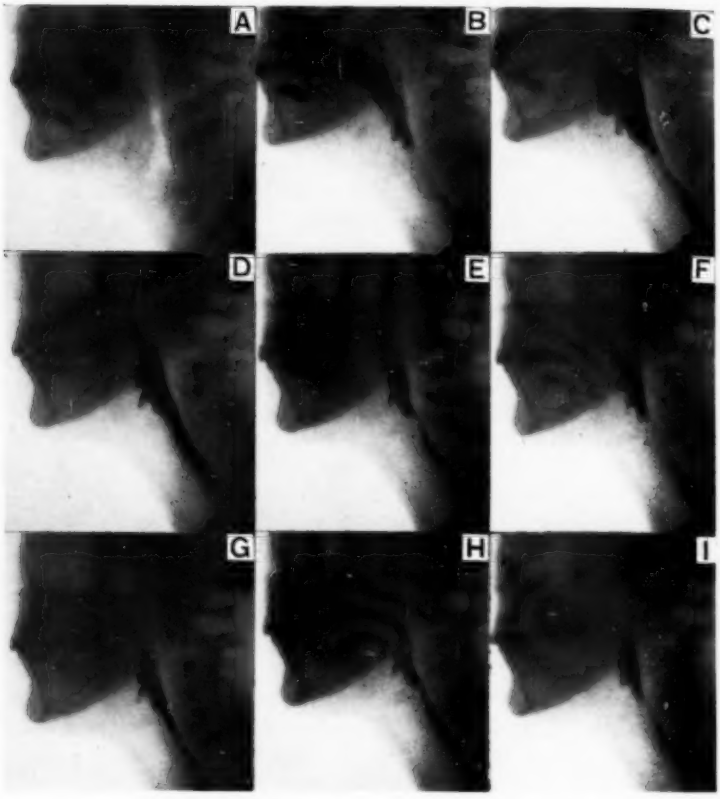

Fig. 3. Defective clearance of pharynx and vestibule due to infiltrative process in woman aged 42 with acrosclerosis. A. Bolus held in mouth. B, C and D. Descent of main mass. Entry of bolus into vestibule. E. Closure of crico-pharyngeus — residue in pharynx. F. Second swallow. G and H. Part of bolus passing into oesophagus. Epiglottis not down-turned. I. Residue in pharynx and vestibule.

The lateral food channels. Antero-posterior and lateral projections of swallowing in the erect position and with the patient's head turned fully both to the right and left are taken. A normal individual usually passes a bolus down both food channels when the head is directed forwards; when the head is turned fully to one side he passes the bolus down the side opposite to which the head is turned (TEMPLETON 1944).

The abnormalities which may be observed are:

1) One food channel may be paralysed, obstructed or otherwise abnormal without the patient complaining of any symptoms.

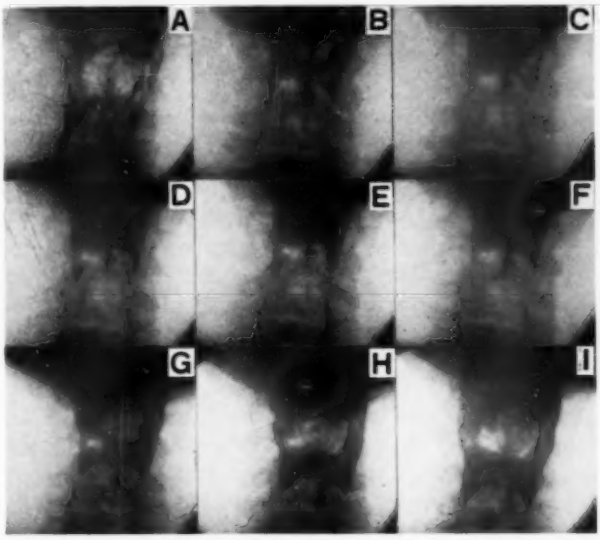

Fig. 4. Defective pharyngeal clearance associated with failure of the crico-pharyngeus to open in male aged 72 with carcinoma of lower oesophagus. A. Large residue from previous bolus. B to I. Arrival of second bolus, elevation of larynx; failure to clear pharynx and re-aeration. None of the bolus passed into oesophagus.

2) Food may pass readily through a paralysed lateral food channel but is not squeezed or stripped from it.
3) In predominantly unilateral palsy it appears that the patient tends to turn the head to the opposite side, so closing the relatively normal channel.

The crico-pharyngeus. The crico-pharyngeus often failed to open completely in patients with bulbar palsy, with the result that the bolus tended to build up in the pharynx. To what extent crico-pharyngeal hold-up can result in inhibition of normal pharyngeal peristaltic movements is not known.

The oesophagus. A hold-up in the oesophagus, at any level, may result in partial inhibition of pharyngeal movements. The residue left in the pharynx may require repeated swallowing actions to clear it; it may hinder the re-expansion of the airway and may sometimes penetrate the larynx and enter the lower airway. Symptoms thus caused may result in faulty diagnosis and treatment. It is recommended that, excluding all obviously ill patients, the initial fluoro-examination should cover the whole oesophagus, the examiner watching the passage of the

bolus with the patient erect and supine. If there remains any doubt the oesophagus should be examined cine-radiographically.

The larynx. Cases of suspected vocal fold paralysis are best examined by tomography supplemented by cineradiography (Ardran, Kemp and Marland 1954). Films are taken in the antero-posterior and lateral projections, on bearing down, on saying 'ee', and on swallowing, to check the action of the vestibular sphincter and to see whether there is any evidence of associated pharyngeal palsy. Many patients with vocal fold palsy omit to mention that they have some associated swallowing difficulties unless questioned. We have seen no patient with vocal fold palsy resulting from surgical injury limited to the recurrent laryngeal nerve, either in the neck or the chest, who also had associated difficulty in clearing the pharynx.

Entry of food into the lower airway may result from paralysis or weakness of the vestibular sphincter, food entering the airway when the larynx is unable to close during the passage of the bolus through the pharynx. The presence of a large residue in the pharynx when swallowing is concluded, may allow food to enter the lower airway when the larynx is opened to re-establish the airway; the laryngeal sphincter mechanism in such cases is working normally.

Comment

The plans outlined above represent our views upon the investigation of pharyngeal and laryngeal palsy at the present time and are not necessarily the best or final, our knowledge being necessarily limited. We stress that a disturbance of function may be due to one of many different causes; the possibility of neoplasm must always be remembered.

Acknowledgments

Our thanks are due to our clinical colleagues for their co-operation. We are especially grateful to Professor C. Wegelius who made it possible for us to examine a series of patients with symptoms following bulbar poliomyelitis.

SUMMARY

The radiologic investigation of disabilities of swallowing in patients with neurologic disorders is described and discussed. Although anatomical and physiological research has been the main aim of the study, the clinical value of the radiologic examination in these cases has been made clear.

ZUSAMMENFASSUNG

Die radiologische Untersuchung der Schluckschwierigkeiten von Patienten mit neurologischen Erkrankungen wird beschrieben und diskutiert. Obwohl anatomische und physiologische Forschungen der Hauptzweck dieser Studie waren, ist die klinische Bedeutung der Röntgenuntersuchung dieser Fälle klargelegt worden.

RÉSUMÉ

Les auteurs décrivent et étudient l'examen radiologique des troubles de la déglutition chez les malades atteints d'affections neurologiques. Bien que cette étude ait eu pour principal objet une recherche anatomique et physiologique, l'intérêt clinique de l'examen radiologique dans ces cas a été mis en évidence.

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RESULTATS DE L'ANGIOGRAPHIE CEREBRALE AU COURS DES HEMIPLEGIES CEREBRALES INFANTILES

par

J. Lefèbvre, J. Lepintre, C. Fauré et *J. Perez*

Il est classique d'englober sous le terme d'hémiplégie cérébrale infantile toute hémiplégie survenue au cours des deux premières années de la vie, étant toutefois exclues celles qui sont dues à une tumeur ou à un abcès. Malgré l'unité du syndrome clinique constitué, l'origine de l'hémiplégie cérébrale infantile est diverse et sa cause exacte est souvent imprécise. Le plus souvent on invoque une encéphalite vraie, un traumatisme natal ou néonatal au sens le plus large du terme, y compris l'anoxie; exceptionnellement une malformation embryopathique a été à l'origine de l'affection.

On a souvent pensé à une origine vasculaire et récemment de nombreux cas ont révélé une phlébite cérébrale. L'origine artérielle est considérée comme rare, les embolies des cardiopathies étant seules mises en cause. Pourtant les artérites cérébrales au cours des maladies infectieuses sont depuis longtemps connues ainsi que les thromboses artérielles par suppuration de voisinage. Leur rôle dans l'hémiplégie infantile acquise a été évoqué par FORD et SCHAFFER.

La démonstration artériographique des thromboses spontanées de la carotide a été réalisée pour la première fois par MONIZ. JOHNSON et WALKER en 1951 rassemblent 101 cas de la littérature, dont 3 enfants seulement. Ces dernières années, les publications sur la thrombose carotidienne de l'adulte sont très nombreuses; par contre les documents artériographiques concernant les enfants sont rares: trois cas seulement mentionnés par LAINE et coll.

L'objet de notre étude n'était pas primitivement de rechercher un facteur artériel dans l'étiologie des hémiplégies cérébrales infantiles mais d'étudier sous un angle large la vascularisation cérébrale. Nous nous

sommes attachés d'abord à l'étude des artères en raison des facilités techniques. Nous apportons ici de simples constatations radiologiques.

Trente enfants ont été examinés, dont le plus jeune a dix mois, le plus âgé dix-huit ans.

Ils sont tous atteints d'hémiplégie cérébrale remontant à la première enfance. Chez 26 d'entre eux l'hémiplégie a été constatée dans les deux premières années; dans 3 cas elle ne l'a été qu'à l'âge de 2 ans, et enfin dans un cas à l'âge de 6 ans (Fig. 1). Nous nous sommes crus autorisés à ajouter ce cas un peu particulier en raison de son intérêt spécial. Un des enfants présente en plus de l'hémiplégie une athétose.

Chaque malade a eu une radiographie simple du crâne et tous, sauf deux, une encéphalographie gazeuse, ou quelquefois une ventriculographie.

Technique. L'artériographie a été faite toujours sous anesthésie générale (à l'éther jusqu'à l'âge de trois ans, au penthotal chez les enfants plus grands), avec intubation, et en circuit demi-ouvert. La ponction des artères a été réalisée par la voie percutanée. (Dans un cas particulier d'obstruction de la carotide au cou, celle-ci a été vérifiée par dénudation, Fig. 3). Chez l'enfant c'est presque toujours la carotide primitive qui est injectée. Pour la vertébrale nous employons la technique de la ponction directe par voie antérieure.

Nous employons une aiguille de 60 × 10 à biseau court avec mandrin. Le produit de contraste utilisé a été exclusivement Diodone à 40 %. La quantité utilisée au cours d'une artériographie varie entre 5 et 8 cc par injection, répétée 4 à 6 fois, et plus. Préalablement nous faisons faire systématiquement un test oculaire. Jusqu'à présent nous n'avons jamais eu d'accident imputable à l'artériographie sur environ 200 artériographies faites chez l'enfant. Parmi les incidents, le plus fréquent est l'hématome du cou qui oblige quelquefois à interrompre l'examen. Un syndrome de Claude Bernard Horner a été souvent observé dans les jours suivants. Nous voudrions souligner que nous n'avons jamais noté de crises convulsives au cours ou à la suite des artériographies; il s'agissait pourtant d'enfants pour la plupart sujets à de telles crises. De même, nous n'avons jamais constaté d'amaurose au décours de cet examen.

Nous ne disposons pas de sériographe automatique. Les cassettes sont tirées à la main par un aide: trois clichés pour le profil, à une seconde et demie d'intervalle. De ce fait, le moment de l'exposition n'est pas absolument identique. C'est la raison pour laquelle nous ne pouvons étudier les veines par cette méthode. Pour les artères, les défauts de remplissage ont toujours été vérifiés par plusieurs injections. Quant à la circulation collatérale, son étude est particulièrement intéressante: la sériographie apporterait certainement dans ce domaine des informations précieuses.

Résultats

L'analyse de nos clichés nous a permis un certain nombre de constatations; si nous essayons de les classer, trouvons d'abord deux grands groupes de faits:

anomalies topographiques, et
anomalies de calibre artériel.

Anomalies topographiques. Ce sont des déplacements des artères parallèles à l'atrophie dont ils sont la conséquence directe.

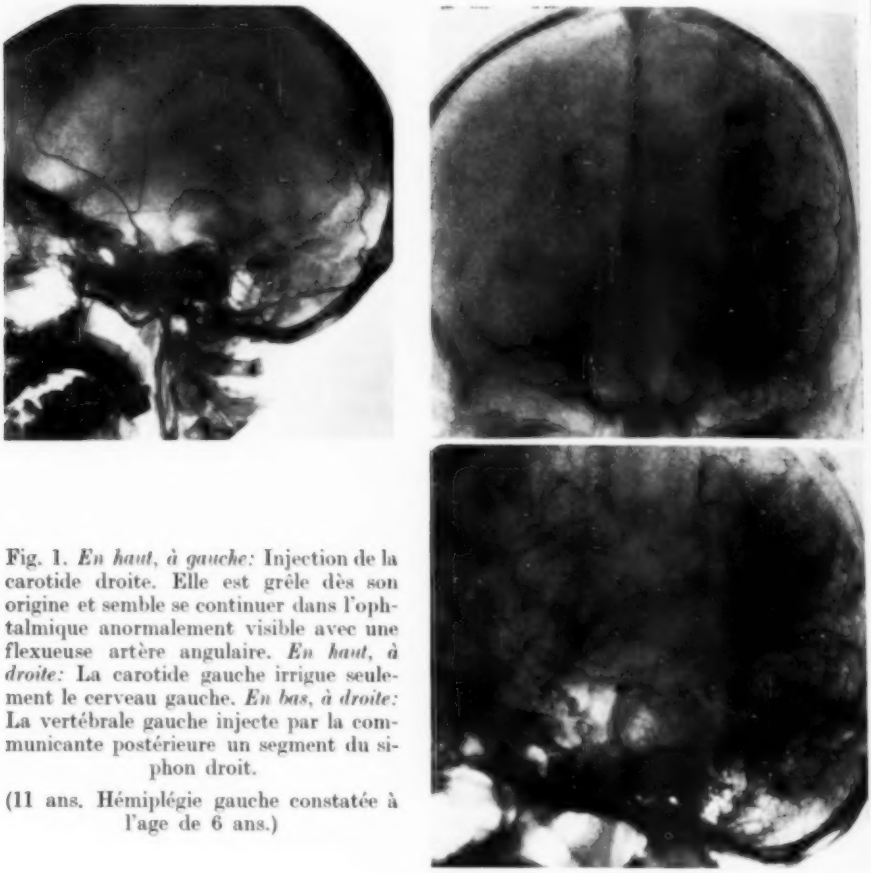

Fig. 1. *En haut, à gauche:* Injection de la carotide droite. Elle est grêle dès son origine et semble se continuer dans l'ophtalmique anormalement visible avec une flexueuse artère angulaire. *En haut, à droite:* La carotide gauche irrigue seulement le cerveau gauche. *En bas, à droite:* La vertébrale gauche injecte par la communicante postérieure un segment du siphon droit.

(11 ans. Hémiplégie gauche constatée à l'age de 6 ans.)

La cérébrale antérieure, sur le cliché de face, suit le déplacement du système ventriculaire vers le côté atrophique. De même, de profil, cette artère décrit une courbe de plus grand rayon, en rapport avec la dilatation ventriculaire; la péricalleuse se rapproche de la voûte. Les branches de la sylvienne sont étirées par l'augmentation de volume du ventricule. Ces anomalies purement mécaniques, secondaires à l'atrophie, ne présentent en elles-mêmes que peu d'intérêt. Nous les avons rencontrées, à un degré plus ou moins marqué mais indiscutables, dans 19 de nos 30 cas.

Anomalies de calibre artériel. Les défauts d'injection vasculaire et les suppléances par la circulation collatérale sont beaucoup plus inté-

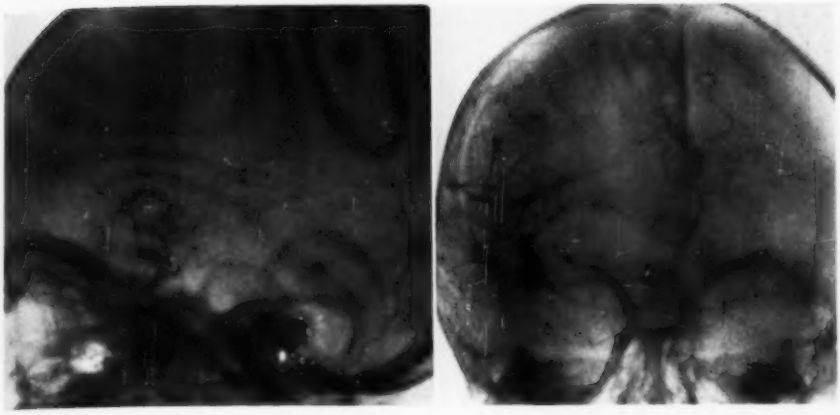

Fig. 2. *A gauche:* Artériographie carotidienne gauche. Les deux cérébrales antérieures sont opacifiées. Les ramifications de la cérébrale moyenne sont pauvres. Anastomose de gros calibre avec l'artère angulaire par l'intermédiaire de l'ophtalmique. Opacification de la cérébrale postérieure. *A droite:* Artériographie carotidienne droite. Les deux cérébrales antérieures sont injectées et sont déplacées vers la gauche. Territoire cérébral moyen normal. ($2^1/_2$ ans. Hémiplégie droite précédée de crises convulsives brachiales droites, constatées à l'age de 1 an.)

ressantes à étudier. Nous les avons rencontrées chez 14 malades. Leur polymorphisme est grand. L'élément le plus important est l'absence ou la pauvreté d'injection d'un territoire artériel plus ou moins étendu. Cette anomalie intéresse essentiellement le térritoire sylvien, soit en partie, soit en entier, parfois même avec interruption de la carotide interne au cou. En réalité, il n'y a jamais une interruption franche et nette mais plutôt une diminution progressive du calibre du vaisseau avec irrégularité de ses contours.

Dans un premier groupe de 3 patients, le défaut d'injection porte sur la carotide interne.

Chez l'un (Fig. 1), ce vaisseau est très mince dès son origine, mais on peut le suivre jusqu'à l'ophtalmique. D'autre part, la vertébrale injecte un segment irrégulier du siphon, la cérébrale antérieure et la sylvienne.

Chez un autre (Fig. 3). la carotide interne est interrompue au niveau du cou à 1.5 cm en aval de la bifurcation, mais, là encore, avec un amincissement progressif et irrégulier.

Chez un troisième. la carotide interne n'a pas été injectée, l'artère ophtalmique était visible; le groupe sylvien injecté par la vertébrale était atrophique.

Fig. 3. *En haut, à droite:* Injection percutanée. La carotide interne droite devenue filiforme par un rétrécissement progressif; les branches de la carotide externe sont injectées, et une artère ophtalmique flexueuse et dilatée est opacifiée par l'intermédiaire de l'artère angulaire. On devine même le siphon carotidien. *En bas, à gauche:* Injection dans la carotide interne gauche. Opacification, outre de son territoire, de la cérébrale antérieure et une partie du groupe sylvien droit (sans compression de la carotide droite). *En bas, à droite:* Injection dans la vertébrale gauche. Tout son territoire plus la totalité du groupe sylvien droit sont irrigués par une volumineuse communicante postérieure. *En haut, à gauche:* Avec dénudation (8 jours plus tard) on vérifie le rétrécissement de la carotide interne droite, un cm au dessus de la bifurcation, et on retrouve la même image radiologique après injection de diodone. On note outre l'opacification du siphon une opacification du tronc basilaire. (2 ans. Hémiplégie gauche, début à 22 mois.)

Dans un deuxième groupe de faits (11 patients) la carotide interne jusqu'au siphon était de calibre normal, et seuls le tronc ou les branches de l'artère cérébrale moyenne étaient altérés. Chez un malade, le calibre de la carotide semble diminuer à partir du siphon (Fig. 4) et l'artère se

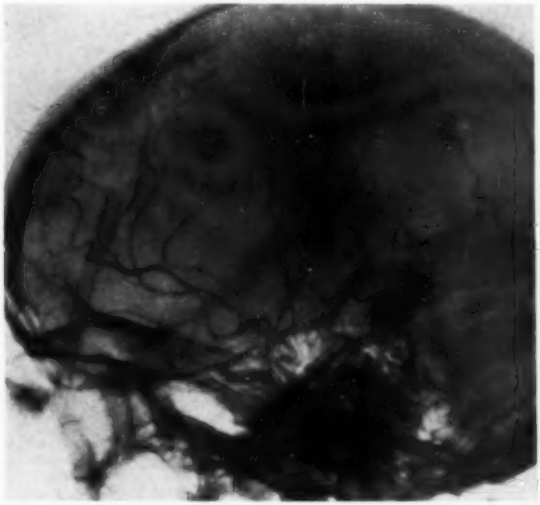

Fig. 4. *Artériographie de la carotide interne gauche.* Le tronc de la carotide s'amincit brusquement au niveau du segment antérieur du siphon. La cérébrale antérieure bien visible se divise en péricalleuse, qui est en place, et en callosomarginale surélevée en atteignant la convexité plus en avant que normalement; les artères de deuxième ordre de ce territoire sont pratiquement absentes. Le groupe sylvien est réduit à quelques fines artérioles. Il existe une plage avasculaire dans la région rolandique.
(18 ans. Hémiplégie droite constatée à l'age de 3 mois.)

continue à plein canal avec la cérébrale antérieure; tout se passe comme si l'altération portait uniquement sur le territoire cérébral moyen.

Chez les autres, à partir d'un siphon normal, ou bien les branches de la cérébrale moyenne sont à peine visibles et réduites à un mince réseau; ou bien réduites en calibre et en étendue, elles sont rétractées, (voir Fig. 2); ou encore les troncs principaux sont grêles, filiformes, sans branche de deuxième ordre; ou enfin certaines branches seulement sont altérées (voir Fig. 5), artères rolandiques le plus souvent.

Ces anomalies morphologiques vasculaires n'intéressent que peu la cérébrale antérieure, et jamais la cérébrale postérieure. Même lorsque la carotide interne est atteinte, comme dans le premier groupe, la cérébrale antérieure, qu'elle soit injectée par une carotide interne grêle et rétrécie, ou par la communicante antérieure, est de bon calibre et contraste avec l'aspect filiforme de la sylvienne. Il est fréquent d'observer (7 fois sur 9), dans le cas où le tronc de la carotide est normal et le territoire cérébral moyen altéré, une extension du domaine de la carotide interne qui opacifie les deux cérébrales antérieures (Figs. 2, 4 et 5) et la cérébrale

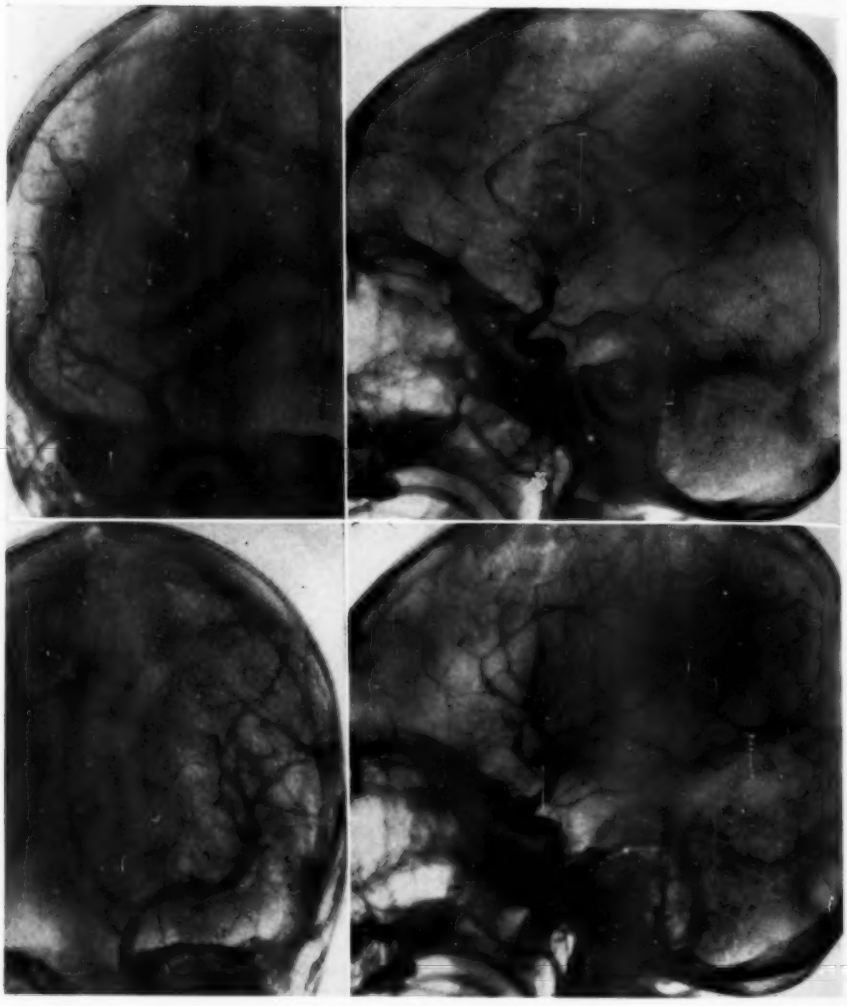

Fig. 5. *En haut:* Injection de la carotide interne droite et irrigation des deux cérébrales antérieures. La cérébrale antérieure droite est dans sa portion pericalleuse, de calibre plus petit que la gauche. On notera le déplacement important vers la droite. Le tronc de la sylvienne est court et grêle; ses ramifications sont pauvres. *En bas:* La carotide interne gauche injecte des vaisseaux de calibre normal. La cérébrale antérieure est déplacée vers la droite. (3 ans. Accouchement difficile, réanimation. Hémiplégie gauche constatée à l'age de 6 mois.)

posterieure (Figs. 2 et 5). Dans certains cas même, la cérébrale antérieure est plus grosse du côté atteint que du côté sain.

Des suppléances vasculaires par la circulation collatérale sont parfois objectivées par l'étude angiographique.

Du fait de l'injection dans la carotide primitive habituelle chez l'enfant, le territoire des deux carotides est opacifié simultanément; ceci n'est en général pas gênant car le réseau carotidien externe est moins intense dans la région qui nous intéresse que celui de son homologue interne, et l'on n'a pas de difficulté à identifier les branches de l'un ou de l'autre vaisseau par leur morphologie. Lorsque la carotide interne est rétrécie, l'opacification de la carotide externe devient presque exclusive; la distinction s'avère plus difficile avec les branches anormalement filiformes de la sylvienne. L'opacification du territoire carotidien externe a par contre l'avantage d'objectiver certaines suppléances vasculaires par la circulation collatérale.

Nous avons constaté plusieurs possibilité de suppléance:

par la carotide interne opposée (Fig. 2);

par la carotide externe du même côté, soit par l'intermédiaire de l'ophtalmique (Figs. 1—3), soit par l'intermédiaire de l'occipitale (Fig. 2);

par la vertébrale (Fig. 2).

Ces suppléances vasculaires ne sont qu'ébauchées; elles paraissent d'autant plus fournies que l'obstruction siège plus en amont sur le vaisseau. Dans les cas où seule étaient pathologiques les branches du territoire cérébral moyen, nous les avons observé 2 fois seulement. Cette suppléance est paradoxale puisque dans ces cas le domaine de la carotide interne est plus étendu.

Peut-être l'utilisation d'un appareil sériographique rapide nous permettrait-elle d'objectiver des anastomoses corticales périphériques telles que celles qu'on pu mettre en évidence par ce procédé ROSEGAY et WELCH.

Rapport entre les anomalies artérielles et l'atrophie cérébrale. Dans 2 cas il n'a pas été pratiqué d'encéphalographie. Dans 4 cas, où clichés simples et pneumographie ne révèlent pas d'atrophie, l'artériographie est normale. Dans 26 cas de dilatation unilatérale, ou à prédominance unilatérale avec déplacement plus ou moins important du système ventriculaire vers le côté malade, nous avons constaté 19 fois des modifications de la topographie vasculaire parallèles au degré de l'atrophie. Par contre, il n'y a aucun parallélisme entre les modifications de calibre, les défauts d'irrigation artérielle et l'importance du processus atrophique. Paradoxalement même, certaines hémiplégies avec grosse dilatation du ventricule du côté atrophique présentent une vascularisation normale quant au nombre et au calibre des artères.

Rapports entre les signes artériographiques et les circonstances étiologiques. Il est impossible, du moins pour les 30 patients que nous avons examinés, d'établir de rapports entre les signes artériographiques et les circonstances étiologiques. Que l'hémiplégie soit survenue à la période néo-natale, ou plus tardivement, qu'il y ait eu ou non des antécédents obstétricaux certains, que l'apparition clinique ait été brutale ou, au contraire insidieuse, non apparente, on retrouve toujours la même proportion (un cas sur deux) d'anomalies par défaut d'irrigation artérielle.

Cependant, il faut retenir que dans les 3 cas où nous avons observé un défaut d'injection de la carotide interne, le début a été secondaire, brutal, avec ou sans syndrome infectieux. Tandis que lorsque seul le territoire sylvien est atteint on observe un début néo-natal dans 7 cas sur 9.

Discussion

Quelle interprétation donner à ces constatations pathologiques quant au nombre et au calibre des artères? Sont-elles la cause ou la conséquence de l'hémiplégie? Les études histopathologiques faites sur les pièces d'hémisphérectomie de certains de nos malades ne peuvent guère nous aider dans cette alternative; un certain nombre d'arguments toutefois plaident en faveur d'une artérite primitive.

RÉSUMÉ

Trente enfants atteints d'hémiplégie cérébrale infantile ont été examinés par artériographie cérébrale. Les anomalies topographiques artérielles en rapport avec les déplacements consécutifs à l'atrophie cérébrale ont été découverts dans 19 cas. Des anomalies de calibre et de nombre, portant essentiellement sur le territoire de la cérébrale moyenne, ont été également mises en évidence, mais dans une proportion beaucoup plus faible des cas. L'artériographie cérébrale a pu en outre objectiver des suppléances vasculaires par l'intermédiaire d'anastomoses avec la carotide externe et la vertébrale.

SUMMARY

Thirty children suffering from cerebral infantile hemiplegia were examined by cerebral arteriography. Arterial topographic anomalies in accord with the displacements resulting from the cerebral atrophy were present in 19 cases. Evidence of an abnormal calibre and number of vessels, particularly in the region of the middle cerebral artery, was also found but in a much smaller proportion of cases. By means of this procedure it was possible to demonstrate collateral circulations through the external carotid and vertebral arteries.

ZUSAMMENFASSUNG

Dreissig Kinder mit cerebraler infantiler Hemiplegie sind mit der cerebralen Arteriographie untersucht worden. In 19 Fällen fand man arterielle topographische Anomalien, welche mit den auf Grund der Hirnatrophie entstandenen Verschiebungen zusammenhängen. Anomalien des Kalibers und der Anzahl der Gefässe, besonders im Gebiet der Arteria cerebri media, wurden ebenfalls beobachtet, jedoch in einer wesentlich geringeren Anzahl der Fälle. Mit Hilfe dieser Untersuchungsmethode war es möglich, Kollateralkreisläufe zwischen der Arteria carotis externa und der Arteria vertebralis zu demonstrieren.

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FROM THE NEUROSURGICAL DEPARTMENT (DIRECTOR: PROF. G. M. FASIANI), SURGICAL CLINIC OF THE UNIVERSITY OF MILANO, ITALY

CEREBRAL ANGIOGRAPHY IN ACUTE BRAIN INJURIES

by

G. M. Fasiani

The major problem a surgeon is called upon to solve when faced with a case of head trauma is whether or not an endocranial lesion necessitating an emergency operation is present. This procedure may be necessary and often life-saving whenever as a result of trauma a space-filling process is taking place inside the cranium. The process is always either the result of severed meningeal vessels with the formation of an extra- or subdural haematoma, or the result of laceration of the brain, often in the frontal and temporal lobes. Ever greater importance is being attributed to these foci of cerebral lacero-contusion in as much as they may become the site of processes leading to the formation of 'space-filling pathologic masses' capable of causing progressive endocranial compression.

The haemorrhage from lacerated pial and parenchymal vessels and the reactive phenomena set up in the adjacent cerebral structures (as a result of local circulatory disturbances and irritative action of the by-products of decomposition from devitalized tissues), form the essential element in these processes. Bloodclots and pulp-like cerebral tissue, surrounded by a more or less extensive zone of oedema, may thus be found at the site of laceration. The presence of such foci are to-day of considerable significance from the viewpoint of indications for surgery.

In a case of head injury the presence of a space-filling process may be inferred from the clinical examination although radiologic endocranial exploration alone can produce the documentation and therefore the precision in diagnosis and localization. Cerebral angiography appears to be the method of choice. It is relatively simple to perform and free from risk and should be carried out in all cases in which the possibility of surgical treatment exists.

We have performed cerebral angiography in 99 cases of recent severe closed head injury, in 43 of which an expansive process was revealed.

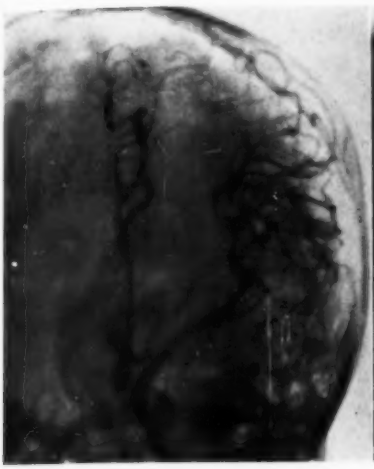


Fig. 1. Laceration of temporal lobe with large haematoma.

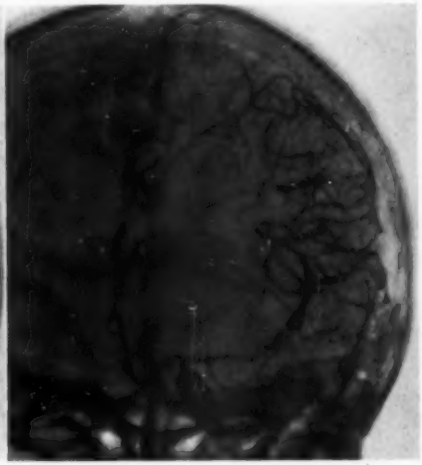


Fig. 2. Laceration of temporal lobe with haematoma.

At operation, an extradural haematoma was found in 12 cases (4 deaths), a subdural haematoma in 5 (1 death), combined extra- and subdural haematomata in 2 (1 death), and cerebral laceration in 24 cases (10 deaths).

The angiographic appearances of extra- and subdural haematomata are well known although this does not seem to be true of the angiographic signs of cerebral laceration with or without intracerebral haematoma. The following four cases are characteristic.

Case 1. Woman, aged 63. Head injury. Free interval for three hours, then coma, right hemiparesis, and left mydriasis. Left carotid angiography (Fig. 1): Medial cerebral artery and Sylvian group displaced upwards to the right; anterior cerebral artery in axis. Operation: Laceration of temporal lobe with large haematoma.

Case 2. Woman, aged 49. Head injury. Immediate and persistent coma; admitted to hospital after 7 days with right hemiparesis and right mydriasis. Left carotid angiography (Fig. 2): Anterior cerebral artery displaced and curved towards the right; medial cerebral artery and the Sylvian group displaced upwards towards the midline and stretched. Operation: Laceration of temporal lobe with haematoma.

Case 3. Woman, aged 60. Head injury. Immediate loss of consciousness; after one hour coma, left mydriasis, and bilateral Babinski. Left carotid angiography (Fig. 3): Anterior cerebral artery displaced and curved towards the right. Carotid siphon and medial cerebral artery displaced upwards towards the midline; medial meningeal artery unaltered; slight detachment of cortical vessels from the theca over the convexity. Operation: Small focus at basi-frontal cerebral lobe laceration and small subdural haematoma.

Fig. 3. Small focus at site of basi-frontal cerebral lobe laceration and small subdural haematoma.

Fig. 4. Extensive focus of laceration in temporal lobe with intracerebral haematoma.

Case 4. Man, aged 44. Head injury. Immediate and persistent loss of consciousness; admitted to hospital after 8 hours of deep coma; left mydriasis and bilateral Babinski. Left carotid angiography (Fig. 4): Syphon markedly displaced towards the midline; anterior cerebral artery much displaced and curved towards the midline; anterior cerebral artery considerably displaced and curved towards the right; medial cerebral artery pushed upwards; Sylvian group displaced upwards towards the midline. Operation: Extensive focus at site of laceration in temporal lobe with intracerebral haematoma.

SUMMARY

Cerebral angiography was performed in 99 cases of recent severe head injury. An expansive process was revealed in 43 of these cases which included 24 cases of cerebral laceration. Four illustrative cases are presented.

ZUSAMMENFASSUNG

Die cerebrale Angiographie wurde in 99 Fällen mit frischen ernsthaften Kopfverletzungen ausgeführt. Ein expansiver Prozess wurde in 43 Fällen, davon 24 mit Hirnzerreissungen, gefunden. Vier illustrative Fälle werden vorgelegt.

RÉSUMÉ

Une angiographie cérébrale a été pratiquée dans 99 cas de traumatisme cranien récent grave. Elle a révélé un processus expansif dans 43 de ces cas, comprenant 24 cas de dilacération cérébrale. Quatre cas sont présentés à titre d'exemple.

AUS DER RÖNTGENABTEILUNG (DOZ. DR. K. DECKER) DER UNIVERSITÄTS-NERVENKLINIK (DIREKTOR: PROF. K. KOLLE) UND AUS DEM HIRNPATH. INSTITUT DER DEUTSCHEN FORSCHUNGSANSTALT F. PSYCHIATRIE (MAX PLANCK-INSTITUT — DIREKTOR: PROF. W. SCHOLZ), MÜNCHEN, DEUTSCHLAND

MEHRFACHE ANGIOGRAPHIEN WÄHREND DER RÖNTGENBESTRAHLUNG VON HIRNGESCHWÜLSTEN

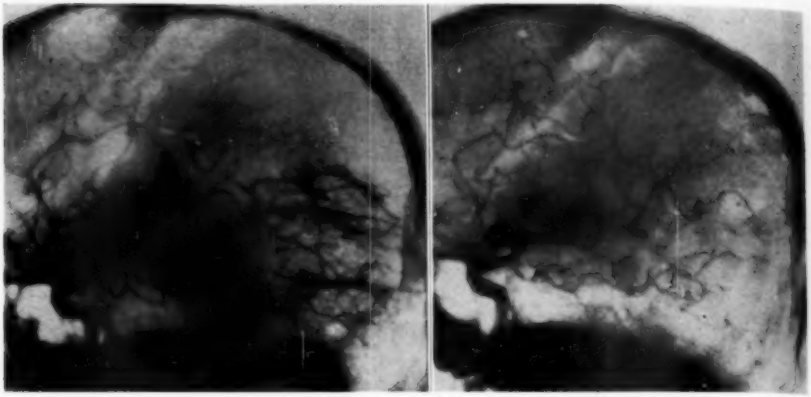
von

A. Breit und *J. Peiffer*

Bei der Strahlenbehandlung von Geschwülsten im Bereich des Körpers ist es meist möglich, den Ablauf des Geschwulstleidens während der Behandlung direkt oder unter Zuhilfenahme des Röntgenleerbildes zu verfolgen. Dies ist am Schädel unmöglich und nur die Angiographie erlaubt es, ohne grössere Belastung des Kranken, das Einsetzen von regressiven Veränderungen der Geschwulst zu erkennen.

Wir führen entsprechende Untersuchungen nun seit Jahren durch und verfügen über einige Erfahrung, die auszugsweise vorgetragen werden soll. Die Röntgenbehandlung sämtlicher Patienten wurde mit dem Pendelgerät von KOHLER, hergestellt von der Firma Siemens, durchgeführt. Die Bilder, die nachfolgend verglichen werden, sind fast ausschliesslich Serienangiogramme mit der Apparatur von Schönander. Es können daher die Angiogrammserien gut mit einander verglichen werden.

Wir trennen unsere Besprechung in die Behandlung der hirneigenen Geschwülste, vorwiegend der Glioblastome, und der hirnfremden Geschwülste, wie der verschiedenen Metastasen oder der Geschwülste an der Schädelbasis. Die Beobachtungen bei der alleinigen Röntgenbehandlung der Glioblastome sind an sich recht widersprechend. Etwa die Hälfte dieser Kranken zeigen am Abschluss der Röntgenbehandlung etwa 4—6 Wochen nach dem ersten Angiogramm keinerlei Veränderungen der Anfärbung der Geschwulst. Bei anderen hat das Geschwulstwachstum sogar zugenommen und in seltenen Fällen kann die Gefässneubildung verschwinden. Dies kann aber trotzdem nur bedingt prognostisch günstig ausgewertet werden. Folgende Beobachtung belegt dies.



a b

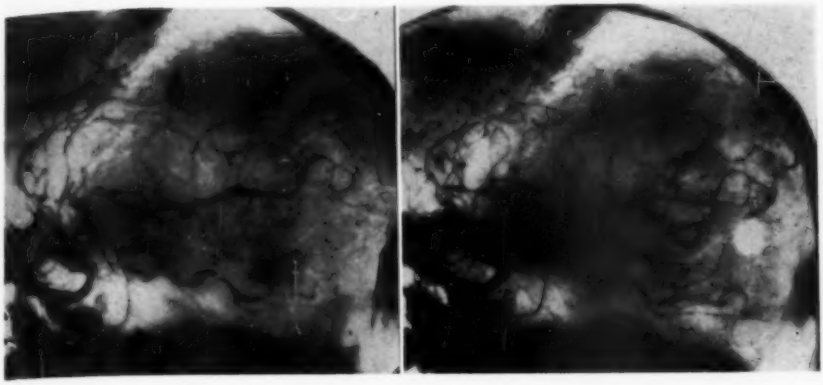
Abb. 1. *Fall 1.* Glioblastom in der occipitalen Region. a) Vor der Behandlung. b) 6 Wochen später nach einer Maximaldosis von 5,400 r/h. Die neubildeten Tumorgefässe sind nicht zu erkennen.

Fall 1. 44-jähriger Patient, seit 3 Wochen Kopfschmerzen und Erbrechen. Bei der Klinikaufnahme war er linksseitig gelähmt und die Carotisangiographie zeigte pathologische Gefässe von dem für Glioblastom typischen Aussehen (Abb. 1 a). Die Dosisverteilung der Röntgenbestrahlung entsprach einer maximalen Herddosis von 5,400 r. Abb. 1 b zeigt den Zustand 6 Wochen nach der Bestrahlung. Die Verlagerungserscheinungen an den Gefässen sind zurückgegangen. Die grosse Gefässneubildung ist nicht mehr zu erkennen. Auch klinisch war eine Besserung eingetreten, die Lähmung zurückgebildet. Der Patient nahm nach 8 Wochen nach Beginn der Bestrahlung seine Arbeit wieder auf. Er starb aber plötzlich 4 Monate später nach der Einnahme von 6 Litern Flüssigkeit.

Fall 2. 54-jähriger Patient, erkrankte 2 Wochen vor der ersten Arteriographie mit Sprachstörungen und Kopfschmerzen (Abb. 2 a). Eine fein vaskularisierte Geschwulst im Parieto-occipitalgebiet wurde gefunden. Eine Probepunktion ergab ein Glioblastom. Nach Abschluss der Röntgenbehandlung war bei etwa gleichbleibenden neurologischen Befund die Geschwulst grösser geworden (Abb. 2 b). Der Kranke lebte in etwa gleichbleibendem Zustand über Monate, verschlechterte sich rasch 6 Monate nach der Röntgenbehandlung und kam wieder in die Klinik. Das Angiogramm (Abb. 2 c) zeigte, dass die Anfärbung weiter zugenommen hatte. Pat. starb 7 Monate nach Beginn der Röntgenbehandlung.

Ebenso uneinheitlich scheinen die Verhältnisse bei den metastatischen Geschwülsten zu sein.

Fall 3. 28-jähriger Patient, wurde wegen einer Schläfenlappengeschwulst röntgenbestrahlt. Er litt unter epileptischen Anfällen und hatte noch keine aphasischen Störungen. Eine Herddosis von 5,200 r wurde verabreicht. Abb. 3 a zeigt der Zustand vor Aufnahme der Behandlung. Diese Behandlung hatte, wie eine Kontrolluntersuchung 4 Monate später ergab, keinen Erfolg (Abb. 3 b). Es wurden daher nochmals 4,000 r mit der Pendelapparatur über dem linken Schläfenlappen verabreicht. Hierauf wurde der Kranke wieder



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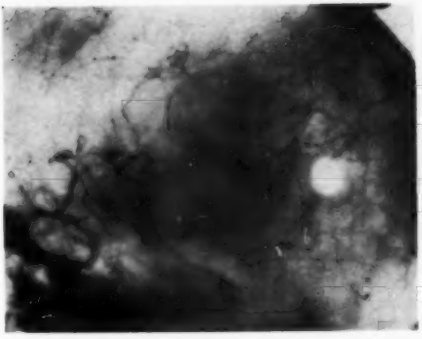

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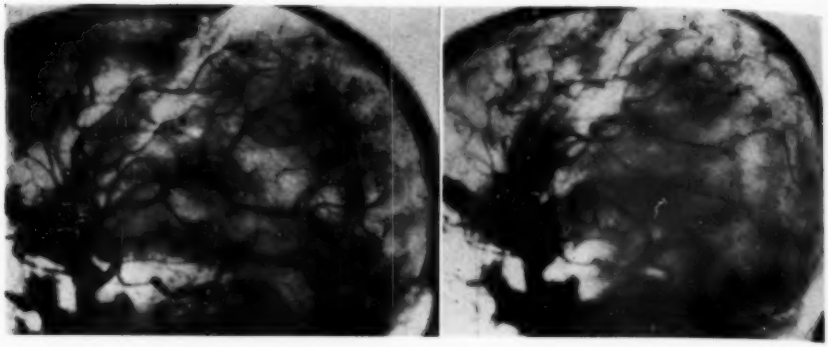
Abb. 2. *Fall 2.* Glioblastom in Parieto-occipitalgebiet. a) Vor der Behandlung. b) 5 Wochen später: die Geschwulst ist grösser. c) 6 Monate später: die Geschwulst ist noch grösser.

arbeitsfähig. Er kam aber 2 Jahre später erneut zur Aufnahme. Bei der Angiographie (Abb. 3 c) war nun die ehemalige Gefässzeichnung im Bereich des Schläfenlappens verschwunden, jedoch hatte sich der Boden der vorderen Hirnarterie geweitet. Der Patient verstarb nach kurzem Aufenthalt in der Klinik. Die Gehirnsektion zeigte eine Geschwulst der hinteren Schädelgrube, die als rundzelliges Sarkom bezeichnet wurde. Im Bereich der bestrahlten Schläfenregion war kein Tumorbefund mehr zu erkennen.

Fall 4. Eine 52-jährige Patientin litt an einem lymphoepithelialen Tumor der Schädelbasis mit Einwachsen in das Innere des Schädels, einem sog. Schmincke-Tumor. 1951 erstmals bestrahlt und 4,000 r an Herde gegeben. Sie zeigte eine erhebliche klinische Besserung und war über Jahre wieder arbeitsfähig. Das Angiogramm vor der Behandlung zeigte zunächst keine wesentlichen Veränderungen. 1953 wurde wegen Neuauftreten von Symptomen eine nochmalige Bestrahlung notwendig, wobei etwa 5,000 r im Bereich der Schädelbasis gegeben wurden. Auch diesmal konnte die Kranke wieder gebessert nach Hause gebracht werden. 1954 kam sie mit Zeichen einer langsam zunehmenden Halbseitenlähmung und erheblichen bulbären Störungen erneut zur Aufnahme. Das Angio-



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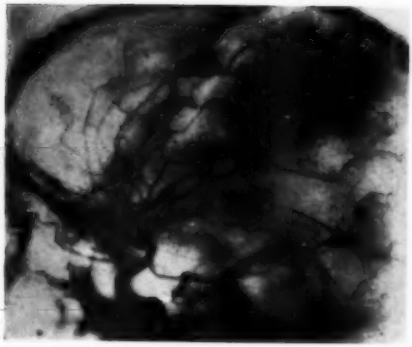

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Abb. 3. *Fall 3.* Metastatischer Tumor im Schläfenlappen. a) Vor der Behandlung. b) 4 Monate nach Röntgenbehandlung mit einer maximalen Herddosis von 5,400r. Keine deutlichen Veränderungen.

gramm zeigte kaum Veränderungen im Bereich der Schädelbasis, liess aber einen erheblichen Ausfall der Gefässe der mittleren Hirnarterie erkennen. Die Patientin starb während des Klinikaufenthaltes.

Die Gehirnresektion zeigte schon makroskopisch eine starke Braunfärbung der basalen Leptomeningen, die — wie die histologische Untersuchung zeigte — auf eine Durchsetzung der Rinde mit Hämosiderinkörnchen zurückzuführen war. Die histologische Untersuchung zeigte neben der Bestätigung des Schmincke-Tumors erhebliche Röntgenspätveränderungen im Bereich der Stammganglien. Die Umgebung des Tumorknotens bot das Bild einer Ödemnekrose mit einer Durchtränkung des Gewebes durch ein eiweissreiches Exudat, mit Koagulationsnekrosen und Schaumzellengranulomen, starker Gefässwandfibrose und bindegewebiger Narbenbildung. Die am Rande des Bestrahlungszentrum gelegenen Zwischenhirnkerne zeigten gut erhaltene Ganglienzellen, sodass wir die von Arnold, Bailey und Harvey beschriebene besondere Empfindlichkeit dieser Zentren nicht bestätigen könnten.

Unsere Beobachtungen zusammenzufassen, ist recht schwierig. Sie zeigen, dass klinischer und angiographischer Befund nur selten parallel

gehen. Andererseits aber scheinen unsere Beobachtungen zu belegen, dass tatsächlich eine Beeinflussung der Geschwulst im Schädelinneren durch die Röntgenstrahlen möglich ist. Besonders die letzte Beobachtung zeigt aber, dass auch die Spätschädigung am Gefässsystem auf dem Angiogramm deutlich werden kann.

ZUSAMMENFASSUNG

An Hand von mehrfachen Angiogrammen vor und nach der Bestrahlung von substanzeigenen und metastatischen Hirngeschwülsten werden Veränderungen des Gefässbildes aufgezeigt. Sie ergeben keine einheitlichen Verlaufsreaktionen. Auf pathologisch-anatomische und histologische Befunde nach Röntgentherapie wird hingewiesen.

SUMMARY

Changes in the appearances of the vessels have been shown in a large number of angiograms obtained before and after the irradiation of primary and metastatic tumours of the brain. No constant course in the reaction was apparent. The pathologico-anatomic and histologic findings following roentgen therapy are described.

RÉSUMÉ

Les auteurs ont observé des modifications dans l'aspect des vaisseaux sur un grand nombre d'angiographies faites avant et après irradiation de tumeurs cérébrales primitives et métastatiques. Cette réaction ne paraît pas suivre une évolution constante. Les auteurs décrivent les résultats des examens anatomo-pathologiques et histologiques après roentgenthérapie.

LITERATUR

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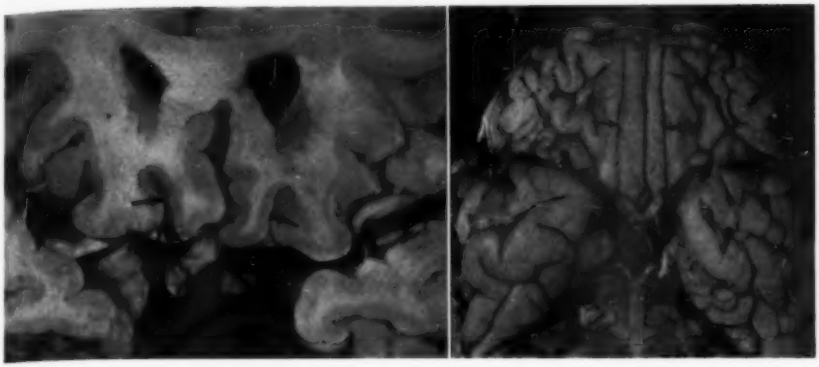
ENCEPHALOGRAPHY OF SELLAR AND PARASELLAR TUMORS, WITH PARTICULAR REFERENCE TO THE ANTEROPOSTERIOR PROJECTION AND OLFACTORY SULCI

by

Joseph Hanelin and *Louis Bakay*

Encephalography has been widely used to demonstrate neoplasms which arise within or about the sella turcica (BALADO, MOREA and DONOVAN; BALADO and PARDAL; DYKE and DAVIDOFF; HEIDRICH; LINDGREN, ROBERTSON; TWINING). These tumors, whether cystic or solid, deform the suprasellar cisterns to an extent which depends upon their size and position. When they are large enough they indent the third ventricle and the lateral ventricles and can cause internal hydrocephalus by obstructing the foramen of Monro. The olfactory sulci may also be distorted by them. Air contrast frequently permits precise delineation of these tumors and may provide a clue to their histological identity. Such exact information is of invaluable aid when planning an operative removal or treatment of the patient by irradiation. It is known that the size and the shape of the sella turcica cannot be used as an index to the suprasellar extension of an adenoma and encephalography can provide the means for such evaluation. The eventual prognosis in a particular case will be highly dependent upon this type of investigation, as the outlook for successful handling, whether surgical treatment or irradiation is used, becomes worse with the increase in size of a tumor. A great variety of tumors of this region including pituitary adenomas, craniopharyngiomas, optic nerve gliomas, meningiomas, chordomas, various malignant tumors, and aneurysms can be identified by encephalography.

Emphasis in the past has been placed upon the lateral projection which permits the delineation of exceedingly small, less than 1 cm, suprasellar extensions of sellar tumors or of small suprasellar lesions.



a b

Fig. 1. Olfactory sulci. a) Coronal section 1 cm from posterior margin. b) Basal view of brain.

It is not, however, generally appreciated that the suprasellar cisterns (cisterna laminae terminalis, cisterna chiasmatis, cisterna interpeduncularis) and the cisterna pontis can be satisfactorily projected in the anteroposterior view. This is true whether the cisterns are normal or pathologically distorted. When the central ray is angulated caudally between 20 and 35 degrees, these cisterns will be thrown clear of the obscuring parnasal sinuses and sphenoid wings.

If the transverse measurement of a suprasellar mass is 2 cm or more, the resulting deformity of the suprasellar cisterns can be detected in the anteroposterior view. If it is less than 2 cm so that no lateral bulging of

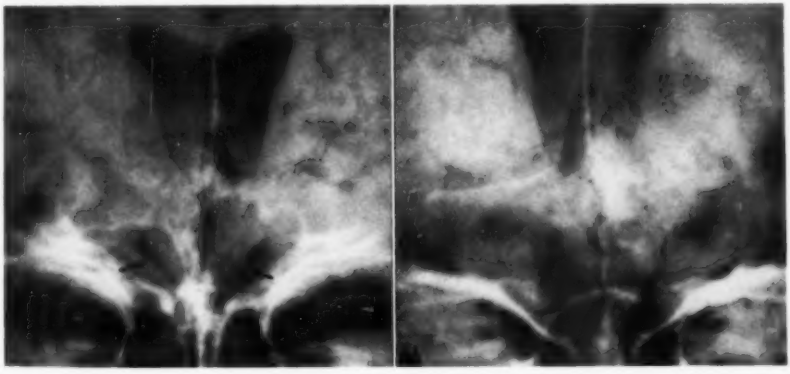
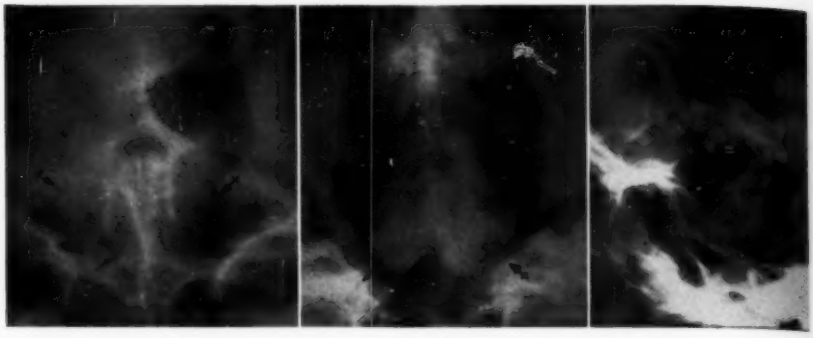


Fig. 2. Normal olfactory sulci. A. p. views with 10 and 20 degrees caudal angulation, respectively.



a b c

Fig. 3. Chromophobe adenoma outlined by air in the suprasellar cisterns. Elevation of anterior portion of third ventricle which is widened transversely (best seen in a). Only the right olfactory sulcus (→) is filled and it is not definitely distorted. Identification of the olfactory sulcus is aided by the sequence of a. p. views. a) and b) A. p. views with 10 and 35 degrees angulation respectively (↔). c) Lateral view.

the cisterns is visible, it may be difficult or impossible to detect such a mass in this projection, as a filling defect may be simulated by incomplete filling of the cisterns. Pressure upon the third ventricle and lateral ventricles is readily ascertained in this view also. At times distortion of the olfactory sulci in the a. p. view may provide the only evidence of a suprasellar mass as was true in the case illustrated in Fig. 5.

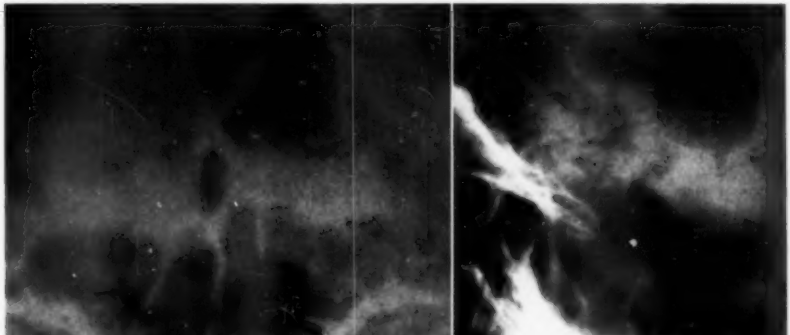


Fig. 4. Cystic chromophobe adenoma. A. p. view with 20 degrees angulation; the right olfactory sulcus makes a rather marked bow but the left is straight; increased space between the sulci.

Fig. 5. Cystic suprasellar cranio-pharyngioma. Distortion of the olfactory sulci.

Olfactory sulci. The olfactory sulci are frequently visualized in the anteroposterior projection and should be distinguished from cisternal air (Figs. 1—2). Although these sulci have been referred to by DAVIDOFF and DYKE, they are mentioned only in reference to the lateral pneumogram, in which view they are difficult to define because they appear as a flat thin layer of air. In the a. p. view, however, the sulci are readily appreciated as two symmetrical narrow air filled clefts, each of which lies 1—2 cm from the midline. The olfactory sulci are situated along the orbital surface of the frontal lobes, parallel to the sagittal plane, and extend the length of the anterior fossa to the tuberculum sellae. They demarcate the lateral margins of the gyri recti. The olfactory tracts lie at the inferior margins of these sulci. The olfactory sulci incline medially as they extend inferiorly; spacing between them is greater posteriorly.

Discussion

While the basal cisterns are generally outlined most advantageously in the brow-up position, the upright lateral view occasionally provides delineation of an uncircumscribed tumor contour with the patient in a supine position. This is particularly true when small amounts of air are used, or when only a limited amount of air can be directed into the basal cisterns due to the large size of the tumor or its strategic position. The stereoscopic lateral films, while not always essential, will at times permit the needed differentiation between air which lies near the midline and that which has accumulated in laterally placed sulci over the convexity of the hemisphere. Small tumors situated anteriorly and abutting upon the cisterna laminae terminalis may also be better outlined by stereoscopy.

The normal suprasellar cisterns are best shown in the axial plane when the central beam is angulated approximately 35 degrees. When these structures are elevated by extrasellar tumor extensions they will be visible with lesser angulation. The olfactory sulci are better differentiated from cisternal air in the axial view by the previously described

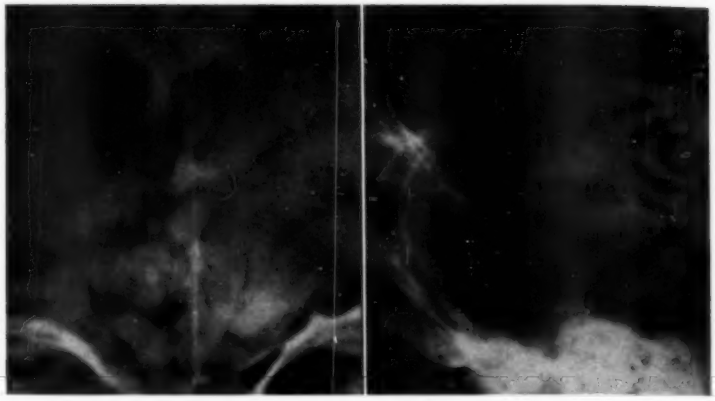


Fig. 6. Unclassified malignant extradural tumor, probably a chordoma. Destruction of the sella, and suprasellar extension of tumor in the a. p. view. Olfactory sulci displaced to the right; left olfactory sulcus is also elevated.

sequence of a. p. views. Because of their location, the olfactory sulci will lie inferior to the basal cisterns in films with caudal angulation, and their most anterior aspects will be situated inferiorly. The characteristic inward slope of these fissures as they incline inferiorly, is also to be emphasized. It is the posterior portions of these sulci which may be deformed by sellar or parasellar lesions. Tumors situated more anteriorly, such as olfactory meningiomas, may also cause deformity of these cisterns, but of their more rostral extensions.

As is true of other paired sulci of the brain, the olfactory sulci may not always be symmetrical even in the normal. Asymmetry must be reasonably marked to be considered significant. The spacing between these sulci may show considerable normal variation. In addition, failure to fill the olfactory sulci or unilateral filling is not necessarily a pathologic abnormality.

SUMMARY

Encephalography provides a method for accurate determination of size, contour and location of tumors which arise within or adjacent to the sella turcica. The value of the anteroposterior projection is emphasized. The anatomy of the olfactory sulci and their radiographic identification in the anteroposterior view are discussed. They may be distorted by tumors in the sellar or parasellar region or by tumors in the anterior fossa situated near the sagittal plane.

ZUSAMMENFASSUNG

Die Encephalographie ist eine Methode zur genauen Festlegung der Grösse, des Umfanges und der Lage von Tumoren, welche innerhalb oder in unmittelbarer Nähe der Sella turcica entstehen. Der Wert der antero-posterioren Projektion als zusätzliches Hilfsmittel zu der bewährten Seitenaufnahme für die Beschreibung von Veränderungen in diesem Hirngebiet wird hervorgehoben. Die Anatomie der Sulci olfactorii und deren röntgenologische Identifizierung auf anterio-posterioren Bildern wird besprochen. Diese Sulci sind häufig sichtbar und sollten von der cisternalen Luft unterschieden werden. Sie können durch selläre und paraselläre Tumoren sowie von in der Nähe der Sagittalebene gelegenen Tumoren der vorderen Schädelgrube verdrängt werden.

RÉSUMÉ

L'encéphalographie fournit une méthode pour déterminer avec précision les dimensions, le contour et le siège des tumeurs qui ont leur origine à l'intérieur ou au voisinage de la selle turcique. Les auteurs insistent sur l'intérêt de l'incidence antéro-postérieure comme complément de la radiographie de profil, dont la valeur est démontrée, pour délimiter les lésions de cette région. Ils étudient l'anatomie des sillons olfactifs et leur identification radiographique sur le cliché antéro-postérieur. Ces sillons sont fréquemment visualisés et devraient être distingués de l'air cisternal. Ils peuvent être déformés par des tumeurs de la région sellaire ou parasellaire ou par des tumeurs de l'étage antérieur situées près du plan sagittal.

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TRANSTENTORIAL HERNIATION OF THE BRAIN AS REVEALED BY THE DISPLACEMENT OF ARTERIES

by

Antony Jefferson and *Philip Sheldon*

Herniation of the uncus and hippocampal gyrus into the tentorial hiatus is a subject which has received attention from clinicians for at least half a century. COLLIER (1904) wrote about "The false localising signs of intracranial "tumours" and although he did not specifically mention herniation he referred to the alterations in the position of the brain stem, proof of which may be obtained post mortem by a deep indentation of the crura cerebri derived from contact with the free edge of the tentorium. KERNOHAN and WOLTMAN (1929) amplified this subject and in their paper illustrated the microscopical findings in such happenings. A year later CLOVIS VINCENT introduced the term "Temporal Pressure Cone" (VINCENT, THIÉBAUT and RAPPOPORT 1930, and VINCENT, DAVID and THIÉBAUT 1936).

Between these papers and those, for example, of SPATZ and STROESCU (1934), JEFFERSON (1938), MOORE and STERN (1938), SCHWARTZ and ROSNER (1941), and SCHEINKER (1945) it has been possible to build up a clinical and pathological picture of the phenomena associated with transtentorial herniation of the brain.

The anterior choroidal artery is intimately related during a part of its course to the optic tract; thus, one part of it marks the position of a portion of the base of the brain. The posterior cerebral artery, as it encircles the brain stem, normally lies at about the level of the tentorial opening (*e. g.* ECKER 1951), and it might be predicted that when these arteries are made visible by cerebral angiography information could be obtained about the site or extent of transtentorial herniation of the brain. This line of thought has been followed in the past by (for example)

ECKER (1951) and TÖNNIS and PIA (1952). The results of the work presented here in most respects confirm, and also amplify, the studies already available.

During angiography the position of the anterior choroidal and the posterior cerebral arteries cannot always be recognised. A series of films has been reviewed to establish the frequency with which these vessels were made visible by the techniques used in this hospital.

Material. The cases reported in this paper have been selected from a large series of carotid angiograms in order to demonstrate abnormalities in the course of cerebral vessels resulting either from transtentorial herniation of the brain or displacement by neighbouring tumours.

In seven of the examples presented it has been possible to correlate the angiographic findings with the post-mortem appearances. To make the correlation more precise cases have been excluded in which long survival, or the presence of haemorrhage or a cyst within the tumour might have caused a significant change in the anatomical features between the time of angiography and of death. Patients with tumours, in whom major surgery had been performed, were also excluded. In the cases presented, the longest time interval between angiography and death was 2 months, and the average time interval in the 7 cases was 20 days.

The remaining 3 patients survived, so that correlation of arteriographic and pathological features was not possible. Of these 3 patients one had a sub-temporal meningioma, one had an uncomplicated subdural haematoma, and one had a right frontal subdural haematoma (complicated by intracerebral changes) which resulted from an aneurysm of the anterior cerebral artery.

In order to establish the frequency with which the course of the anterior choroidal and posterior cerebral arteries could be recognised, the following films were reviewed:

1) A series of one hundred unselected angiograms performed on adult patients with intracerebral tumours (all types of tumour pathology and all degrees of raised intracranial pressure were included in this series);

2) A comparable series of fifty angiograms of adult patients in whom no "surgical" lesion was discovered and in whom the arteriograms were regarded as normal.

Results

Frequency of filling of the anterior choroidal and posterior cerebral arteries. The frequency with which the course of these arteries was identified is set out in Table 1.

The anterior choroidal artery was recognised in the lateral view in about the same proportion of cases in the two groups. In the antero-

Table 1

	Lateral view		A. p. view	
Anterior choroidal artery	"Tumour" cases	"Normal" cases	"Tumour" cases	"Normal" cases
Course satisfactorily identified..	72 %	86 %	23 %	66 %
Filled, but course uncertain ...	17 %	12 %	10 %	20 %
Artery not identified	11 %	2 %	67 %	14 %
	Lateral view		A. p. view	
Posterior cerebral artery	"Tumour" cases	"Normal" cases	"Tumour" cases	"Normal" cases
Course satisfactorily identified..	53 %	24 %	33 %	20 %
Filled, but course uncertain ...	7 %	14 %	14 %	14 %
Artery not identified	40 %	62 %	53 %	66 %

posterior view it is often more difficult to make out the course of the anterior choroidal artery, not only because the contrast is poorer, but also because in the early part of its course it may be obscured by the posterior cerebral artery and later in its course may be obscured by several of the small "perforating" arteries. In the antero-posterior view there is a difference between the two groups in the frequency with which the course of the anterior choroidal artery was recognised. Among the "normals" it was satisfactorily identified in 66 per cent of cases, and among the "tumour" cases in only 23 per cent of cases. In some instances this may have been because it was more often obscured in the tumour cases by the posterior cerebral artery. In the "normal" group, satisfactory filling of the posterior cerebral artery was seen in the lateral view in 24 per cent of cases. A further 14 per cent showed evidence of posterior cerebral filling, but it was insufficient to allow the course of the vessel to be accurately determined; in about half these patients the posterior communicating artery was well filled, but at, or shortly beyond its junction with the posterior cerebral artery, it was no longer possible to see the course of the vessel. Presumably the blood flowing from the basilar artery either checked or diluted the contrast medium. On the lateral view there is a pronounced increase in the frequency of posterior cerebral artery filling in the "tumour" group — 53 per cent in the "tumour" cases compared with 24 per cent in the "normal" group. The possible reasons for this will be discussed later. The posterior cerebral artery was identified somewhat less frequently in the antero-posterior view in both the "normal" and the "tumour" groups.

The anterior choroidal artery in the lateral view. The course of the anterior choroidal artery has been described by ECKER (1951) and more recently by MORELLO and COOPER (1955), who discussed some of the normal variations in its course as seen in cerebral arteriograms. Fig. 1 shows gross upward displacement of the anterior choroidal artery by a

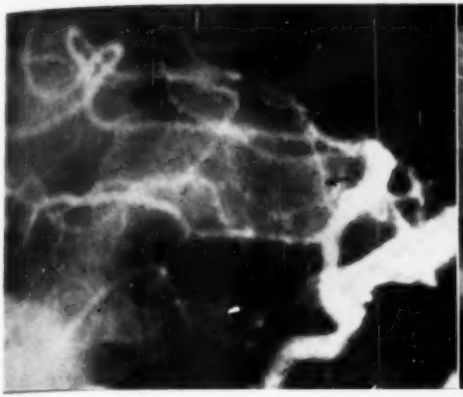


Fig. 1. Right subtemporal (cavernous sinus) meningioma. Right carotid arteriogram, lateral view; gross elevation of anterior choroidal artery (↑) and stretching of posterior cerebral artery (↕). Pathological circulation within the tumour is visible.

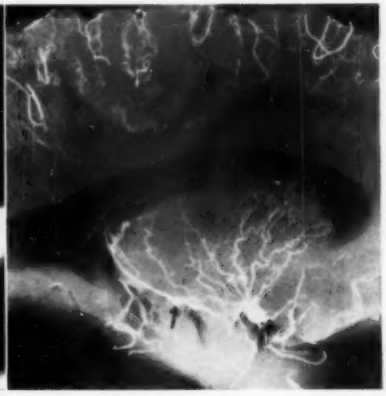


Fig. 2. Median sagittal brain section. Arteries injected at autopsy with opaque medium. Arrow (↑) indicates kink in the anterior choroidal artery where it enters the temporal horn.

meningioma arising from the floor of the right temporal fossa and involving the side of the cavernous sinus. The nature and position of this lesion was confirmed at operation. Since the anterior choroidal artery for a part of its course lies in intimate relationship to the optic tract, it is not surprising that in this case there was unmistakable clinical evidence of compression of the right optic tract; (viz.: a left homonymous hemianopia: VAR, Finger counting; VAL, J. 6). It is surprising that such upward displacement of the artery, carrying with it part of the central portion of the base of the brain, should have been compatible with comparative well-being of the patient.

A slight "step" in the anterior choroidal artery approximately 2 cm from its origin has frequently been seen, and this is in agreement with the observations of ECKER (1951). An irregularity in the anterior choroidal artery at the appropriate distance from its origin has been noticed in the post-mortem examination of normal brains, and it is suggested that this "step" corresponds to the point at which the artery enters the temporal horn. Fig. 2 shows the appearance in a median sagittal brain slice with the arteries injected post mortem. This patient had no intracranial disease.

Downward displacement of the anterior choroidal artery by a glioma involving the basal ganglia is exemplified in Fig. 6a. In the lateral arteriogram it can be seen that the downward displacement ends in a

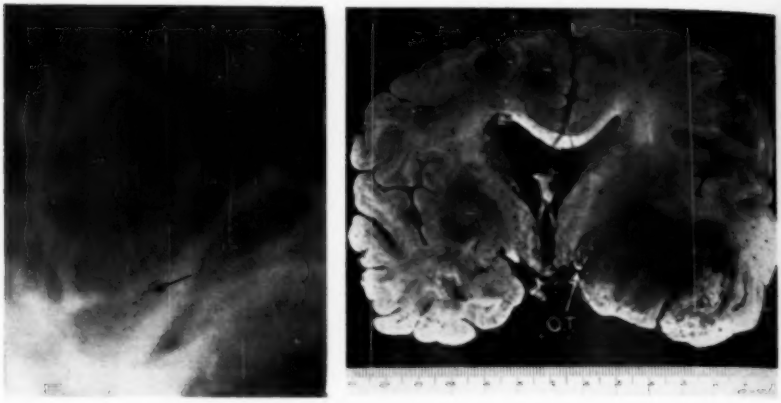


Fig. 3. Glioblastoma of left basal ganglia and left temporal lobe. a) Left carotid arteriogram, antero-posterior view. Anterior choroidal artery (↑) displaced medially. b) Coronal section of brain (print reversed for easier comparison). Optic tract (O. T.), corresponding to anterior choroidal artery, displaced medially. (Interval between angiography and death was two months.)

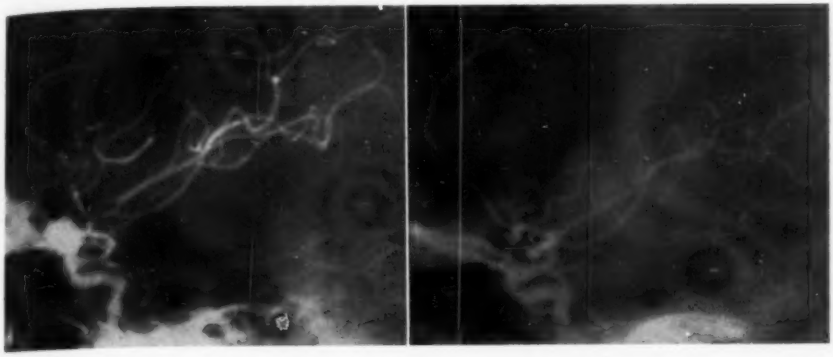
hook-like curve as the artery ascends to a higher level. A cross section of the frontal region of the brain of this same patient (Fig. 6c) confirms that the left optic tract is depressed downwards, and this anatomical feature corresponds with the arteriographic finding.

The anterior choroidal artery in the antero-posterior view. Because it is often difficult to define the course of the anterior choroidal artery in the antero-posterior projection the only deviation of this artery presented here is medial displacement of its first part.

Fig. 3 shows the left carotid arteriogram of a man with a glioma involving the left basal ganglia and the deep portions of the left temporal lobe. The anterior choroidal artery approaches the midline more nearly than is usual. A cross section of the brain shows the left optic tract infiltrated by tumour, and displaced medially, as would have been anticipated from the arteriogram. Medial displacement of the optic tract (and therefore of the first part of the anterior choroidal artery) does not occur only with deep-seated tumours but may result from a superficially placed tumour with diffuse enlargement of the temporal lobe.

The posterior communicating and the posterior cerebral arteries in the lateral view. Herniation of the uncus and the anterior portion of the hippocampal gyrus is frequently revealed by depression of the posterior communicating artery and the first portion of the posterior cerebral artery.

Fig. 4 shows left carotid arteriograms of a patient who had an aneurysm of the anterior communicating artery which had ruptured into



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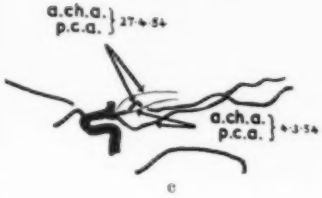

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Fig. 4. Right sub-dural haematoma with aneurysm of anterior communicating artery. Left carotid arteriograms, lateral views. a) 4/3/54. Anterior choroidal, posterior communicating and anterior portion of the posterior cerebral arteries depressed. b) 27/4/54. Transtentorial herniation relieved; decompression; aneurysm largely obliterated. c) Composite lateral tracings to compare the position of the vessels (a ch. a. — anterior choroidal artery; p. c. a. — posterior cerebral artery).

the frontal lobes and from thence into the subdural space on the right side. Fig. 4a shows the state immediately before operation, at a time when she was unconscious and had dilated pupils that did not respond to light. At operation the subdural haematoma was evacuated, a portion of both frontal lobes was sucked away, the base of the aneurysm was largely occluded, and a right subtemporal decompression was performed. Fig. 4b shows the appearance nearly eight weeks later when there was no longer clinical evidence of transtentorial herniation of the brain. There is a striking difference in the position of the posterior communicating artery (and also of the anterior choroidal artery) on the two occasions. The change in position of the posterior communicating artery and the anterior portion of the posterior cerebral artery was presumably related to the relief of the considerable herniation of the uncus and the anterior portion of the hippocampal gyrus. However, herniation of the uncus does not invariably lead to depression of the posterior communicating artery.

Fig. 5 shows an example of sharp upward displacement of the posterior communicating artery associated with pronounced herniation of the uncus (as well as of the remainder of the hippocampal gyrus). Probably

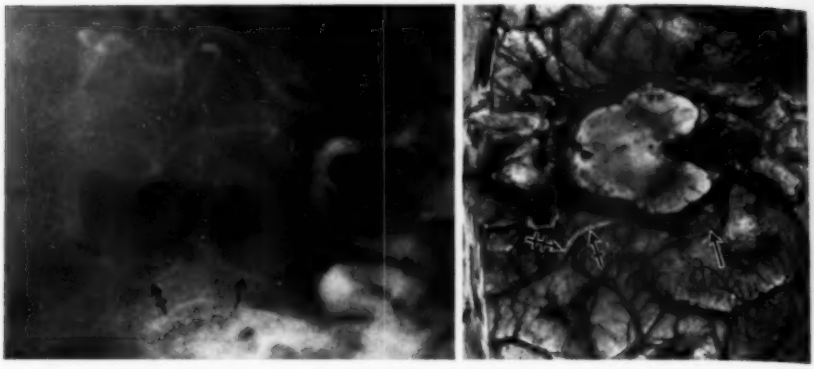

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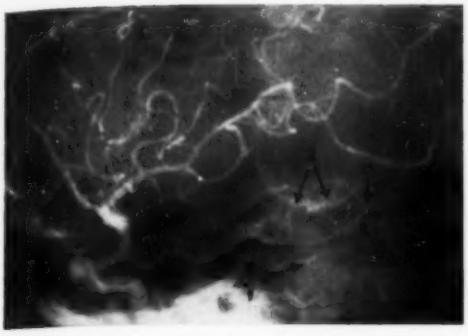
Fig. 5. Glioblastoma of right temporal lobe. a) Right carotid arteriogram; lateral view. Air from a preceding study remains in temporal horn. b) View of base of brain (print reversed). Right posterior communicating artery deflected sharply upwards; posterior cerebral artery then loops down onto hippocampal gyrus (↑) and returns to cleft between brain stem and hippocampus. From thence its postero-lateral branch runs over herniated hippocampal gyrus (↕), and artery is sharply kinked (*) where it passes over free edge of tentorium. Left cerebral peduncle is pressed against the left uncus; there was a small infarct in the territory of the left posterior cerebral artery. (Interval between angiography and death was three days.)

the course adopted by the posterior communicating artery depends upon its initial relationship to the uncus, and this will determine whether the artery becomes depressed, elevated, or displaced medially as herniation progresses.

The recognition by arteriography of herniation of the hippocampal gyrus is not confined to changes involving its anterior portion.

Comparison of the views (a) and (b) in Fig. 5 shows how the main postero-lateral branch of the posterior cerebral artery describes a loop which outlines the herniated hippocampal gyrus. Further comparison of these figures shows that the kink where the artery crosses the free edge of the tentorium is more marked in the arteriogram than in the photograph of the base of the brain. This indicates that the degree of herniation during life was greater than that found post mortem.

Fig. 6 shows the findings in a patient with a glioma involving the posterior portions of the basal ganglia bilaterally. The drawing of the base of the brain shows that the herniation involved all portions of the hippocampal gyrus, to a greater extent on the left than on the right. The branch of the posterior cerebral artery, marked 1 in the figure, makes a loop over the hippocampal gyrus opposite the middle of the brain stem.



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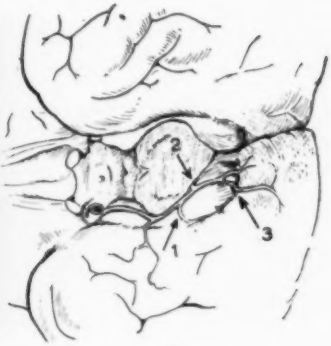

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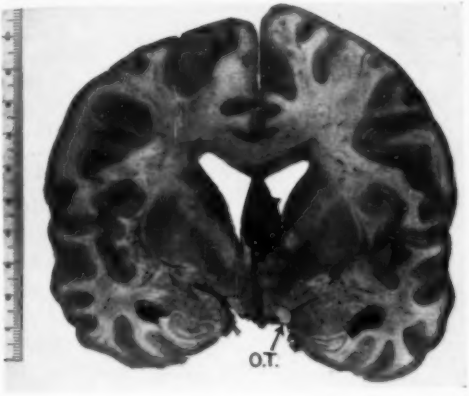

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Fig. 6. a) Left carotid arteriogram; lateral view. Anterior part of anterior choroidal artery (↘↗) depressed, sharp upward "step" where it enters temporal horn. Posterior communicating and posterior cerebral arteries are also displaced downward. Branch 1 outlines herniated middle portion of the hippocampal gyrus. The postero-medial branch 2 passes between the brain stem and the medial surface of the hemisphere. Two divisions of branch 3 each show a kink where they pass the free edge of the tentorium. b) Drawing of the base of the brain (print reversed). Arteries numbered as in (a). c) Coronal section of brain to show anterior extremity of tumour. Left optic tract (O. T.) depressed. This abnormality may be correlated with the position of the anterior chorodial artery. (Interval between angiography and death was thirteen days.)

The branch marked 2 passes on to the medial aspect of the hemisphere, lying between hemisphere and brain stem, and is presumably destined for the calcarine cortex. The branch marked 3 lies beneath the herniated posterior portion of the hippocampal gyrus, and the points at which the subdivisions of this artery are kinked by the posterior free margin of the tentorium are visible both in the lateral arteriogram and on the base of the brain.

Fig. 7 has been selected to show a gross example of herniation of th whole of the hippocampal gyrus, which in this instance was widely in filtrated by tumour. The posterior communicating artery, and the front

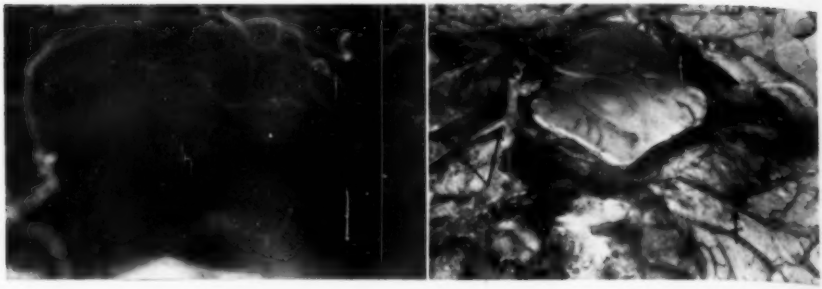

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Fig. 7. Extensive glioblastoma of left temporal lobe. a) Left carotid arteriogram, lateral view. b) View of base of brain after removing brain stem and cerebellum, to show course of arteries (print reversed). Posterior communicating artery (↖ ↗) has been dissected from the tumour which surrounded it. Two main branches of the posterior cerebral artery can be identified in a) and b). In the arteriogram the herniated hippocampal gyrus can be recognised and the position of the tentorial edge is marked by kinks in the course of the vessels (↑ and ←). Compare post mortem findings where herniation appeared less pronounced. (Interval between angiography and death — 36 hours.)

part of the posterior cerebral artery are tightly stretched as well as depressed. The stretching of these arteries resulted from their intimate relationship to the tumour. At the post-mortem examination, part of the tumour had to be resected before the posterior communicating artery could be seen. Herniation of the posterior portion of the hippocampal gyrus was clearly demonstrated on the lateral arteriogram in which two large branches of the posterior cerebral artery showed well defined kinks at the free edge of the tentorium. At autopsy, the course

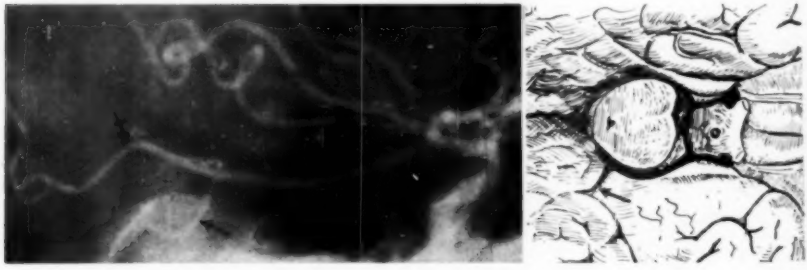

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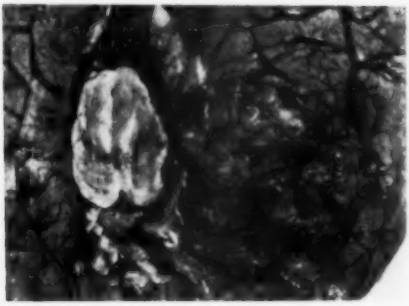
Fig. 8. Glioblastoma of corpus callosum. a) Right carotid arteriogram, lateral view. Posterior cerebral artery bowed downward, and also kinked posteriorly (↖↘) by tentorial edge. b) Drawing of base of brain (print reversed). Arrow (↖) indicates lateral branch diving into sulcus and simulating hernia of hippocampal gyrus.

a



b

Fig. 9. (Same patient as in Fig. 7.) a) Antero-posterior arteriogram. b) View of base of brain (print reversed). Posterior cerebral artery shows concavity, (↑) comparable to indentation of left cerebral peduncle. Artery also angulated round lateral aspect of midbrain (←). Anterior choroidal artery displaced nearly to midline (→).

of these arteries was confirmed. On this occasion also the degree of herniation found at post mortem was less than that which was apparent during life, for the sharpness of the kinks shown on the angiogram was considerably greater than those found at autopsy.

Fig. 8 illustrates an appearance which might have been taken to indicate a gross hernia of the posterior portion of the hippocampal gyrus. Study of the base of the brain shows that the right hemisphere is somewhat fuller than the left, in consequence of which the right posterior cerebral artery as viewed from below is more prominent than is the left throughout its course. This corresponds to the diffuse downward bowing of the posterior cerebral artery visible on the lateral arteriogram. The possible confusion arises because of the course of the branch marked with an arrow. This branch appears to describe a downward loop, but the termination of this loop is unlike the kinks previously illustrated. Moreover it would be anatomically impossible for the tentorial edge to lie both at the termination of this loop and at the point where the main branch of the posterior cerebral artery is undoubtedly kinked. Examination of the base of the brain shows that the appearance of this loop results from the relevant branch diving into a sulcus. The drawing of the base shows the point at which this artery leaves the surface of the brain, and its further course was confirmed by dissection.

Another source of confusion might arise from the fact that the pos-

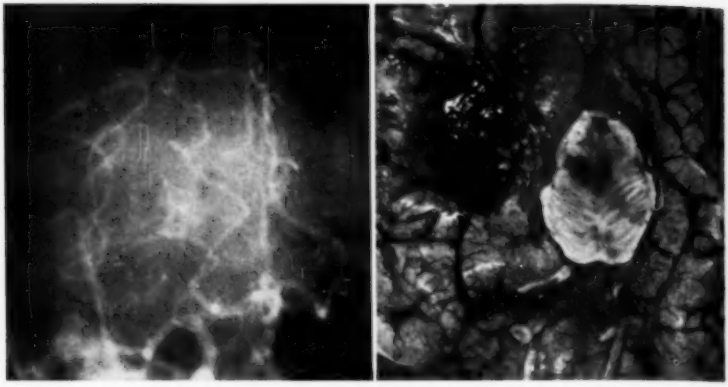


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Fig. 10. Glioblastoma of right posterior temporal region. a) Right carotid arteriogram, antero-posterior view. Spontaneous filling of both posterior cerebral arteries and of basilar artery and branches. b) View of base of brain (print reversed). Posterior part of right posterior cerebral artery stretched and displaced antero-medially. Anterior part of left posterior cerebral artery (between uncus and peduncle) shows concave distortion (↑). (Interval between angiography and death fourteen days.)

terior cerebral artery as it encircles the brain stem frequently describes a curve which is convex downwards. However, this may be distinguished from the effect of transtentorial herniation by the position of the more distal portions of the vessel. The distinction between normal and abnormal becomes more difficult when the termination of the basilar artery is low and the posterior communicating artery becomes incorporated in the downward curve of the posterior cerebral artery.

The course of the posterior communicating and the posterior cerebral arteries in the antero-posterior view. The position of the posterior communicating and posterior cerebral arteries in the antero-posterior view was discussed briefly by Engeset (1948) and subsequently by Tönnis and Pia (1952) and by Pia (1953). These arteries conjointly describe a sinuous curve, and the changes which occur with transtentorial herniation of the brain result in distortion of this curve, together with medial displacement of the main axis of the vessel. In addition, the distal portions of the branches of the posterior cerebral artery can be seen to be kinked by the free edge of the tentorium, and such kinks can usually be correlated with those seen in the lateral view. In assessing the position of the posterior cerebral artery it is important to be aware that apparent differences in its course may result from changes in the angle of projection.

Fig. 9 shows distortion and displacement of the posterior cerebral artery by a huge left temporal glioma, as seen in the antero-posterior

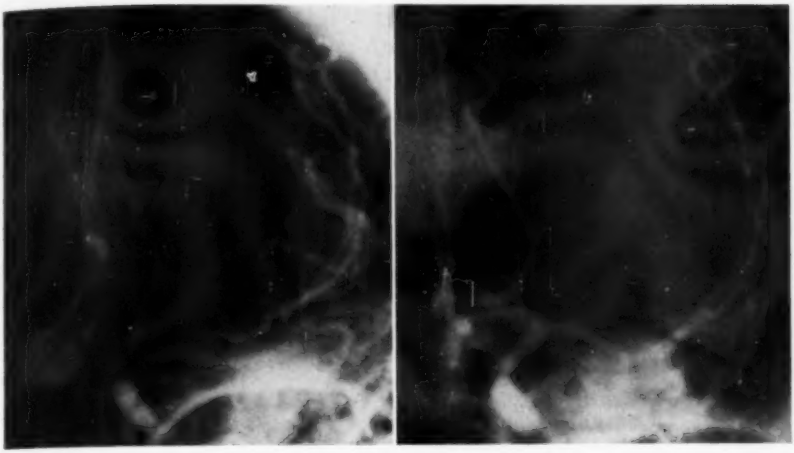

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Fig. 11. Same case as in Fig. 4. Left antero-posterior arteriograms. a) 4 March 1954. Pericallosal arteries, deflected to left and large aneurysm. b) 27 April 1954. At time of transtentorial herniation, posterior cerebral artery concave in anterior portion (↑), angulated at lateral aspect of brain stem (↕), straightened posteriorly (↖ ↗). After relief of pressure, posterior cerebral artery resumes normal sinuous course.

projection. The anterior portion of the posterior cerebral artery takes a course that is concave instead of the normal convex curve. As it passes round the lateral aspect of the brain stem it is angulated. It is also clear that the whole axis of the artery is displaced medially. The base of the brain shows that the left cerebral peduncle has been deformed by pressure from the herniating tumour so that its lateral aspect is concave. The appearance of the brain stem thus corresponds in this, and in other respects, to that which might be anticipated from the arteriogram.

Fig. 10, in which there has been spontaneous bilateral filling of both posterior cerebral arteries, illustrates another point of interest. The most informative abnormality is to be seen in the posterior limb of the right posterior cerebral artery as it passes round the brain stem. This part of the artery is stretched and straightened and its course should be compared with that of the other side. Post-mortem examination showed a tumour adjacent to the distorted part of the right posterior cerebral artery. The left cerebral peduncle had also been deformed by pressure against the left uncus, as was demonstrated by the arteriogram and at post-mortem examination. A similar deformity of the contralateral cerebral peduncle was found at autopsy in the case shown in Fig. 5. Furthermore on this occasion the inferior surface of the occipital lobe contralateral

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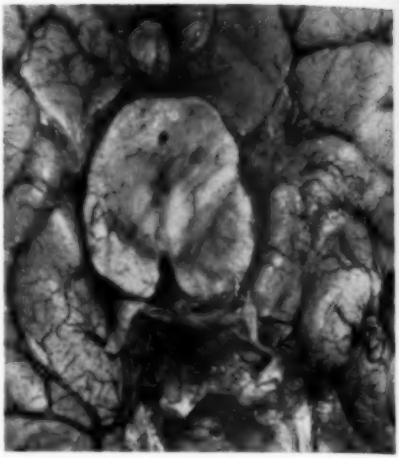

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Fig. 12. Glioblastoma of left hemisphere. a) Tracings of posterior cerebral artery in antero-posterior projection. Posterior communicating artery, at later examination, displaced medially — also course of posterior cerebral artery distorted. b) View of base of brain. Posterior communicating artery (↖↗) displaced medially by herniated uncus. (Interval between 2nd angiogram and death 7 weeks.)

to the tumour showed a small area of infarction. It is suggested that one of the factors contributing to the development of this infarct may have been partial occlusion of the left posterior cerebral artery as it lay between the cerebral peduncle and the uncus.

Fig. 11 shows the arteriograms in the antero-posterior view of the case already illustrated in Fig. 4. At the stage when this patient was affected by raised intracranial pressure with a right frontal subdural haematoma, the left carotid angiogram showed that the posterior cerebral artery was concave in its anterior portion, was angulated at the lateral aspect of the brain stem, and appeared straightened posteriorly. When the examination was repeated nearly eight weeks after operation it showed that the course of the artery was restored almost to normal.

Fig. 12 shows tracings from the antero-posterior projections of left carotid arteriograms performed at an interval of nearly six months. This patient had a left hemisphere glioma with considerable hippocampal herniation observed at autopsy. In the figure it can be seen that the course of the artery had become angular, and it is possible to deduce from this projection alone that the posterior communicating artery had been displaced medially by the projecting uncus.

Subdural haematoma with clinical evidence of tentorial herniation. On the basis of the information derived from these studies an attempt has

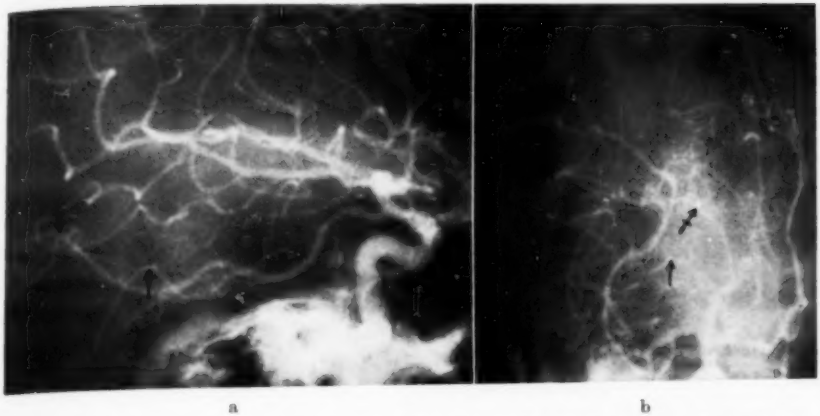

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Fig. 13. Right chronic subdural haematoma. Right carotid arteriogram. a) Lateral view. b) Antero-posterior view. Posterior cerebral artery displaced downwards and medially. Postero-lateral branch (↑) and main trunk (↕) are both kinked as they cross tentorial edge.

been made to correlate the clinical and angiographic findings in a patient with clear clinical evidence of transtentorial herniation of the brain. There was no post-mortem confirmation of the herniation, since this patient had a subdural haematoma which was evacuated.

The patient was a female, aged 64, who had begun to feel giddy two months before admission. Five weeks before operation the giddiness became more intense and was associated with vomiting. Two weeks later there was an episode of unconsciousness, following which a right third nerve palsy was observed. Following this she was drowsy and remained in bed. She complained of dysphagia. There was bilateral ptosis and limitation of upward gaze. On the day of the operation a right-sided angiogram was performed and the arteriograms may be seen in Fig. 13. In the lateral view, there is general depression of the posterior cerebral artery, though not of the posterior communicating artery. There are two points posteriorly, where branches of the posterior cerebral artery appear to be kinked by the free edge of the tentorium. In the antero-posterior view, both these kinks may be identified, and there is gross medial displacement of the axis of the posterior cerebral artery so that its normal course is no longer recognisable.

At operation a large right-sided subdural haematoma was found and was evacuated. (The left side was normal.) The patient subsequently made an excellent recovery in spite of having passed through a period during which there was considerable distortion of the midbrain.

Discussion

It is interesting that there has recently been widespread attention directed to the problem of recognising transtentorial herniation of the brain by radiological means. The work of ENGESET (1948) on the angio-

graphic visualisation of the posterior cerebral artery was not followed up until ECKER (1951) discussed some of the distortions of the anterior choroidal artery and of the posterior cerebral artery which result from transtentorial herniation of the brain. The following year TÖNNIS and PIA (1952) introduced a classification of the various patterns formed by the posterior cerebral artery in the lateral arteriogram in transtentorial herniation of the brain. However, they did not publish pathological confirmation of these patterns, and their types 111a, 111b and 111c do not, in the present writers' view, definitely represent an abnormal state of affairs. The downward curve of the posterior cerebral artery ends so far anteriorly that they may well have been misled by one of the normal patterns of the posterior cerebral artery, referred to above. PIA (1953) wrote further on the arteriographic recognition of tentorial herniation but comparison of his Figs. 3 and 4b indicate that he may not have been fully aware of the difficulties in interpretation which may arise from a change in projection on the antero-posterior view. LINDGREN (1954) published an excellent picture in the antero-posterior projection of the posterior cerebral artery distorted by herniation of the temporal lobe. However, in this work the recognition of transtentorial herniation by arteriography was not pursued.

ECKER and RIEMENSCHNEIDER (1955) illustrated diagrammatically displacement of the posterior cerebral artery by a hernia of the hippocampal gyrus. This diagram does not seem to be accompanied by any corresponding arteriograms, but it closely matches the findings recorded in Fig. 5 in the present paper.

NIEMEYER (1955) among a series of rough sketches suggested that the branches of the posterior cerebral artery, running off the herniated hippocampal gyrus, would show an acute kink as they regained the level of the tentorium. There is no clear angiographic evidence to document this, but the cases recorded in Figs. 6 and 7 by the present writers probably illustrate the changes which he had in mind.

If the arteriographic recognition of transtentorial herniation of the brain is to be of use, then information about the position of the posterior cerebral artery must be available in a reasonably large proportion of the patients. ENGESET (1948) gave some interesting figures concerning the frequency with which the posterior cerebral artery may be seen. He observed 250 patients from the Department of Neurology with posterior cerebral artery filling in 14.8 per cent. In 188 patients from the Neurosurgical section, filling was observed in 35.1 per cent. However, some doubt was cast on the significance of these figures because most of the neurological cases had a percutaneous carotid puncture and most of the neurosurgical cases had angiography by direct exposure of the carotid artery. The present writers would suggest that these figures have a special

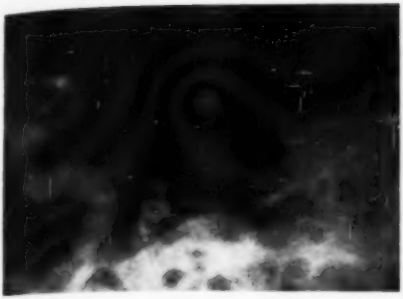

Fig. 14. Left frontal glioblastoma with gross tentorial herniation confirmed at autopsy. Left carotid arteriogram with spontaneous filling of basilar artery; anterior choroidal and posterior cerebral arteries displaced downwards; corkscrew deformity of basilar artery (↑).

significance, because they have found a similar difference between two corresponding groups of patients when the technique of angiography remained unchanged. It is suggested that the high incidence of posterior cerebral artery filling among the tumour cases follows from a change in the blood flow in the circle of Willis during transtentorial herniation of the brain. Thus, mere filling of the posterior cerebral artery by carotid injection may, under certain circumstances, prove to be one of the ancillary signs diagnostic of tentorial herniation. It should be stresed that of the wellmarked examples of transtentorial herniation illustrated in this paper half of them showed evidence of spontaneous filling of the basilar artery. Fig. 14 shows an example of a left frontal glioma with gross transtentorial herniation (confirmed at autopsy) with spontaneous filling of the basilar artery. This artery appears like a corkscrew in the lateral view.

LINDGREN has drawn attention to the association of transtentorial herniation with longitudinal buckling of the basilar artery. It is difficult to believe that such distortion of this vessel can occur without changes in the blood flow through it, and indeed the fact that the basilar artery fills at all during carotid angiography may be taken as an indication that the blood flow in the distal part of the basilar artery is not normal.

Because the brain stem and the cerebellum move downwards during transtentorial herniation (SCHEINKER 1945) it seems probable that the anterior surface of the pons and medulla may become pressed against bone. In these circumstances the vertebral or the basilar arteries might be compressed. It is conceivable that changes in arterial pressure relationships contribute to the formation of terminal brain stem haemorrhage. FISCHER-BRÜGGE (1951) and also TÖNNIS and PIA (1952) have both drawn attention to changes in the blood flow in the circle of Willis associated with tentorial herniation. However, none of them appears to have paid attention to deformation of the basilar or vertebral arteries as one factor responsible for these changes.

There can be no doubt that since the posterior cerebral artery fills in 60 per cent of tumour cases (and probably in a higher proportion of those with tentorial herniation) the course of this artery may frequently

be informative. In the opinion of the writers the radiological recognition of transtentorial herniation already provides a service to clinical neurology in two respects. In the first place it has revealed that the degree of displacement is greater in life than post mortem studies would suggest, and in the second place it has shown how gross a distortion of the midbrain is compatible with a satisfactory functional recovery. It is the hope of the writers that with increased experience mild degrees of tentorial herniation may be recognised by radiological means before the clinical signs of such an occurrence are certain. Indeed, in the case illustrated in Fig. 6, the occurrence of herniation of the hippocampal gyrus was not recognised clinically, though it was apparent radiologically. The importance to the clinician of obtaining proof of transtentorial herniation lies in the consequent compression of the midbrain which brings with it disturbances of consciousness (*e. g.* CAIRNS 1952). Such neurological changes may well influence the line of treatment offered to the patient.

In some centres patients who are neurologically "grossly deteriorated" are not considered suitable for major surgery or for radiotherapy. In deciding treatment for any given patient it is important to be able to assess how much, if any, of their neurological deficit may be attributable to midbrain compression. Not only are precise neurosurgical measures now available for dealing with the problem of herniated portions of the brain (*e. g.* SCOVILLE 1955), but sometimes spontaneous improvement may occur, as in a patient recently observed in this clinic.

The patient (R. I. No. 192432/55) entered hospital with clear-cut clinical and arteriographic signs of transtentorial herniation of the brain and seemed so deteriorated that no treatment was contemplated after a small aspiration biopsy had indicated that she had a left parieto-occipital astrocytoma. Some five days after the biopsy this patient made an unexpected, progressive and spontaneous improvement which cast doubt upon the correct diagnosis, but revealed her as now suffering from only mild neurological deficits which were compatible with continued useful life in the home. After the improvement, a further angiogram showed that the herniation had greatly decreased.

Whatever the future potentialities of the radiological recognition of transtentorial herniation of the brain it remains at the moment such a relative innovation that its usefulness to the clinician cannot yet be finally assessed.

Acknowledgements

We are grateful to Mr. JOE PENNYBACKER for permission to record details of patients under his care. During the preparation of this paper one of us (A. J.) held a Nuffield Foundation Fellowship.

SUMMARY

Cases from a large series of carotid angiograms have been selected to illustrate the occurrence of transtentorial herniation of the brain as shown by displacement of the anterior choroidal, posterior communicating and posterior cerebral arteries. Herniation of different portions of the hippocampal gyrus, including the uncus, may be recognised. The majority of cases have been selected to allow correlation between the post-mortem material and arteriograms.

Fifty "normal" and 100 abnormal angiograms have been reviewed to assess the proportion in each group in which the anterior choroidal and the posterior cerebral arteries can be satisfactorily identified in both the lateral and the antero-posterior projections.

ZUSAMMENFASSUNG

Aus einer grossen Anzahl von Karotisangiographien sind Fälle ausgewählt worden, um das Auftreten transtentorieller Hernien des Gehirnes zu illustrieren. Diese werden durch Verlagerung der vorderen Choroidalarterien, der hinteren kommunizierenden Arterien und der hinteren Hirnarterien aufgezeigt. Hernien der verschiedenen Abschnitte des Gyrus hippocampus einschl. des Uncus können erkannt werden. Die meisten Fälle sind so gewählt worden, dass sie eine Korrelation zwischen Sektionsmaterial und Arteriogramm erlauben. Fünfzig „normale" und 100 pathologische Angiogramme sind studiert worden um in jeder Gruppe festzustellen, in welchen Proportionen die vorderen choroidalen und die hinteren cerebralen Arterien in der seitlichen bezw. in der anteroposterioren Projektion zuverlässig identifiziert werden können.

RÉSUMÉ

Les auteurs ont choisi, parmi une importante série d'angiographies carotidiennes, des cas de hernies transtentorielles se traduisant par des déplacements des artères choroïdienne antérieure, communicante postérieure et cérébrale postérieure. Il est possible de reconnaître la herniation de différentes portions de la circonvolution de l'hippocampe, y compris l'uncus. La plupart des cas ont été choisis de façon à permettre la confrontation des pièces d'autopsie et des artériographies. Cinquante angiographies «normales» et 100 angiographies anormales ont été examinées pour déterminer dans chaque groupe la proportion des cas où on peut identifier de façon satisfaisante, aussi bien sur les radiographies de profil que sur celles de face, les artères choroïdienne antérieure et cérébrale postérieure.

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